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ACTA RADIOLOGICA

EDITA PER SOCIETATES RADIOLOGICAS DANIÆ, FENNIÆ, HELVETIÆ, HOLLANDIÆ, NORVEGIÆ ET SUECIÆ

VOL. V FASC. 5 — 15:X 1926 — N:o 27

ÜBER DIE BEDEUTUNG DER BETASTRAHLEN FÜR DIE BIOLOGISCHE RÖNTGENSTRAHLENWIRKUNG

von

Dr. Adolf Liechti, Bern

In einer Zeit, wo die reine, exakte Wissenschaft der Röntgenologie, die Physik und darin namentlich die Atomphysik und die elektromagnetische Lichttheorie die gewaltigsten Fortschritte zu verzeichnen haben, wo die Elektrotechnik uns, was Apparatur anbetrifft, Mittel mit fast unbeschränkten Möglichkeiten in die Hand gibt, bleibt die Frage nach der Art und Weise, wie wir durch Bestrahlung in den Ablauf normaler und pathologischer Funktionen eingreifen, trotz dem immensen klinischen Material, trotz den unübersehbar vielen experimentellen Tatsachen, und trotz der stattlichen Zahl von Theorien mit mehr oder weniger grossem heuristischen Wert, noch unbeantwortet. Der Grund hierfür liegt nicht nur in der Schwierigkeit der Dosimetrie, sondern auch in der Tatsache, dass der Mechanismus der biologischen Funktionsabläufe selber, nicht oder nur ungenügend bekannt ist. Ferner ist folgendes zu beachten, und das scheint mir das wesentlichste Moment zu sein, das strahlenbiologische Experimente erschwert: Die unmittelbaren Bestrahlungsfolgen werden bald durch sekundäre Reaktionen und Allgemeinwirkungen getrübt; ja noch mehr, diese Letzteren übertönen die Primärwirkung sicher dann, wenn die Strahlenwirkung überhaupt manifest wird, d. h. zu einer Zeit wo die Bestrahlung längst aufgehört hat zu wirken. Es wird aber stets ein Ding der Unmöglichkeit bleiben, später die Grenzen zwischen primären und sekundären Wirkungen zu ziehen.

Durch die Kompliziertheit dieser Verhältnisse kommt es denn nur zu oft zu widersprechenden Resultaten der verschiedenen Autoren sowohl bei experimentellen Untersuchungen, als auch bei der Interpretation von klinischen Beobachtungen. In diesem Zusammenhang

möchte ich nur an die Blutuntersuchungen bei röntgenbestrahlten Individuen erinnern. Ich denke an die Befunde bezüglich des Refraktometerwertes (Herzfeld & Schinz, Klewitz, Mahnert & Zacherl, u. a.), des Cholesteringehaltes (Strauss, Mahnert & Zacherl, Konrich & Scheller, v. Babarczy, Levy Dorn & Burgheim), des Cholins (Werner & Schwarz, Gähwyler), der Senkungsgeschwindigkeit, der P_H. Reaktion u. s. w. Da wo Tatsachen endlich feststehen, kann in den seltensten Fällen die Genese der Strahlenwirkung erschlossen werden. Ich glaube, man geht am besten so vor, dass man von dem gesicherten Boden der Physik ausgehend, nach und nach über möglichst einfache physiko-chemische Versuchsanordnungen, die als partielle Phantome für die lebende Zelle gelten dürfen, auf das biologische Gebiet vorstösst und nicht umgekehrt, dass man von den sekundären Erscheinungen zurück auf die Primärvorgänge schliesst.

Ein Strahl kann im Gewebe nur wirken, wenn er absorbiert wird. Die Absorption, der *physikalische Primärvorgang*, ist der erste Akt der Röntgenstrahlenwirkung. Das Wesen der Absorption elektromagnetischer Schwingungen besteht ganz allgemein in einer Veränderung des physikalischen Gefüges der Atome und Moleküle der Materie, in unserem Falle des lebenden Gewebes. Dieser neue Zustand ist im wesentlichen nur durch die Anwesenheit von energiereicheren Atomen gekennzeichnet. Dieselben sind von vorneherein diffus und wohl regelmässig, entsprechend der grossen Zahl der einzelnen Absorptionsereignisse, im Gewebe verteilt. Eine Wirkungsmöglichkeit ist also in jedem Punkte der Zelle — gleiche Strahlung und gleiche Substanz vorausgesetzt — in gleicher Weise gegeben. Die energie-reicheren Atome können aber an bestimmten Stellen z. B. an bestimmten Teilen der Zelle oder des Zellverbandes, eine ganz besondere Wirkung physikalisch-chemischer Art hervorrufen. Der physikalische Primärvorgang führt also wahrscheinlich zu einer in bezug auf die Zelle inhomogenen Wirkung. Diese neue Veränderung stellt den zweiten, wichtigen, noch nicht aufgeklärten Akt der Strahlenwirkung dar. Ich möchte ihn den *biologischen Primärvorgang* nennen. Er ist die Folge des vorherigen und ist charakterisiert und gegeben durch Gestalt und Zusammensetzung der Zelle, ähnlich wie die Absorption gegeben ist durch die Zusammensetzung der Materie ganz allgemein. Der Effekt, den der biologische Primärvorgang bewirkt, kann zeitlich mit der Bestrahlung identisch sein, d. h. er kann mit der Bestrahlung beginnen und mit der Unterbrechung derselben enden. Er kann dieselbe aber auch überdauern. Die Vergrösserung des Energieinhaltes, die durch diese Zustandsänderung zustande kommt, kann ganz durch die durch den physikalischen Primärvorgang gelieferte Energie gedeckt werden, oder die Strahlung kann nur dazu

verwendet werden, um in der Zelle selbst ablaufende Kreisprozesse zu steuern. Die Bestrahlung würde sich dann zum Bestrahlungseffekt verhalten wie Reiz zu Reizerfolg. — Alle diese Vorgänge haben, wenn die Intensität der Bestrahlung gross genug war, Veränderungen zur Folge, die den Gesamtstoffwechsel der Zelle und somit auch den des Zellverbandes stören. Dieselben überdauern jedenfalls die Bestrahlung oder treten sogar erst nach Unterbrechung derselben auf. Die betroffene Zelle kann sich nach kürzerer oder längerer Zeit wieder restitutieren oder es kann der Tod derselben eintreten. Alle diese Folgen die die Zelle als ganzes betreffen, die zellphysiologisch und vielleicht schon morphologisch erfassbar sind, sind *Sekundärwirkungen am Orte der Strahlenabsorption.* Sie sind besser erforscht als der biologische Primärvorgang, aber schlechter als der pysikalische Primärvorgang. — Diese drei ersten Akte, physikalischer und biologischer Primärvorgang sowie Sekundärwirkungen am Orte der Strahlenabsorption, spielen sich lediglich im primär bestrahlten Gebiete ab. Durch die veränderte Zellfunktion, die in einem veränderten Stoffwechsel zum Ausdruck kommen muss, wird auch das Milieu verändert, der Gewebssaft, weiterhin das Blut. Diese letzten Veränderungen sind zusammengefasst unter dem Begriff der *sekundären humoralen Strahlenwirkungen.* Diese ihrerseits können bewirken: 1. Reaktionen im bestrahlten Gebiet. 2. Rückwirkungen auf andere Organe (beiderorts funktionell-regulatorische, morphologische).

Was die Frage des physikalischen Primärvorganges anbelangt, ist derselbe durch die Atom- und Quantentheorie sowie durch die elektromagnetische Lichttheorie weitgehend geklärt. Sein Endeffekt ist für die biologische Wirkung in der Emission von β-Strahlen gegeben. Dass die β-Strahlen für die Röntgenstrahlenwirkung auf die lebende Zelle von ausschlaggebender Bedeutung sind, habe *ich* (Kl. W'schr. 3,825, 1924) in Anlehnung an MILANI und DONATI sowie HALBERSTÄDTER & MEYER in folgenden Versuchen erwiesen. Ich suchte die Fragen zu beantworten: 1. In welcher Abhängigkeit steht die Intensität der biologischen Wirkung der Sekundärstrahlen von der Ordnungszahl Z der sie emittierenden Elemente. 2. Welchen Einfluss hat die Qualität der Primärstrahlung auf den Sekundärstrahleneffekt. 3. Welcher Qualität und welcher Art sind die hierbei wirksamen Röntgenstrahlen. Als Sekundärstrahler wurden sowohl blanke Metalle von $Z = 26$ bis $Z = 82$, sowie deren Salze verwendet. Das flächenhafte radiosensible System war eine auf Agarplatten frisch ausgesäte Prodigiosuskultur. Resultate: 1. Der maximale Verstärkungsfaktor beträgt für blanke Metalle ca. 40 bis 50, für deren Salze ca. 25 (auf Ag, Sn, Pb & Au). 2. In der aufsteigenden Reihe der nach Z geordneten Metalle zeigt sich in bezug auf die Sekundärstrahlenwirkung auf den Prodigiosus

unter den gegebenen Versuchsbedingungen ein Maximum bei den Elementen mit Z = 47—50. Die folgenden Elemente zeigen ein relatives Minimum, das bei Z = 58 oder etwas höher liegt. Ein zweites Maximum ist bei Z = 80. Dieses letztere hat absolut eine ca. gleich grosse Intensität wie das erste. 3. Wird das Intensitätsmaximum der Primärstrahlung nach der weichen Seite verschoben, so verschiebt sich einerseits das erste Wirkungsmaximum der Sekundärstrahlung nach der Seite der Metalle mit kleinerem Z, anderseits sinkt die absolute Grösse des zweiten Maximums herab. 4. Durch ein 0,1 mm dickes Paraffinfilter werden 14/15 sämtlicker wirksamen Sekundärstrahlen absorbiert. Die Wirkung der noch durchdringenden Strahlen steigt dann linear mit der Ordnungszahl.

Aus diesen Versuchen geht hervor, dass die wirksame Strahlung jedenfalls eine äusserst weiche sein muss. Die Wirkungssteigerung kann bedingt sein 1. durch die sekundäre Streustrahlung, 2. durch die sekundäre Fluoreszenzstrahlung, oder 3. durch die sekundäre β-Strahlung. Die erste hat aber annähernd (Compton-effekt) die gleiche Härte wie die Primärstrahlung, sie müsste also das dünne Paraffinfilter praktisch ungeschwächt durchdringen. Das gleiche gilt von der sekundären Fluoreszenzstrahlung, trotzdem sie allerdings teilweise bei den in betracht kommenden resonierenden Atomen bedeutend weicher ist, als die Streustrahlung. Somit bleibt nichts anderes übrig, als die Wirkung auf die weiche β-Strahlung zurückzuführen. Ein weiterer Beweis, dass diese Annahme stimmt, liegt darin, dass die experimentell erhaltenen Curven der Wirkungssteigerung sich hinsichtlich ihrer Abhängigkeit sowohl von der Ordnungszahl des sie emittierenden Elementes als auch von der Härte der Primärstrahlung mit den von Holthusen für die Elektronenemission geforderten Curven decken.

Die gleichen Resultate wie bei den Bakterien erhielt ich auch am Säugetiergewebe (Kl. W'schr. 5.545, 1926). Es wurden die gleichen blanken Metalle wie oben verwendet. Als radiosensiblen Indikator wurde diesmal die Kaninchenhaut benutzt. Werden die Metalle auf das Kaninchenohr gelegt und von der andern Seite her bestrahlt, so zeigt sich eine, an makroskopischen Veränderungen beurteilt, geringe Steigerung der Röntgenstrahlenwirkung durch Sekundärstrahlung. Die Intensität steigt von Z = 30 an aufwärts linear mit der Ordnungszahl. Metalle mit Z unter 30 haben keine verstärkende Wirkung. Bei subcutaner Lagerung der Metalle kann keine von der Hautoberfläche her sichtbare Veränderung festgestellt werden. — Bei den Versuchen am Kaninchenohr wurden die weichen sekundären β-Strahlen zum grössten Teil durch das Stratum corneum und die obersten Schichten des Stratum germinativum absorbiert, bevor sie zu den pigmentbildenden Zellen gelangten (Pigment = Indikator). Im

zweiten Versuch hat das Corium sämtliche wirksamen Strahlen abgehalten. — Im fernern wurden kolloidale Metalle (Ag als Elektrargol und Au + Sn als Goldpurpur) im Kaninchenhoden untersucht. Dabei konnte gegenüber dem Kontrollhoden keine Wirkungssteigerung festgestellt werden, weil einerseits die Dichte der sekundärstrahlenden Atome zu gering (schätzungsweise 0,5 %) und weil andererseits die radiosensible Schicht der Spermatogonien durch die Membrana propria und z. T. durch die Schicht der Sertolischen Zellen vom Strahler getrennt ist.

Wenn auch alle diese Versuche nur die Wirkungs*steigerung* als β-Strahlenwirkung beweisen, so ist doch zuzugeben, dass jene äusserst weiche Strahlung, die wir als Elektronenstrahlung erkannt haben, einen gewaltigen Effekt zeitigen kann. Wenn dies aber die von Metall ausgehenden β-Strahlen können, dann können es auch die im Gewebe selbst durch die Primärstrahlen ausgelösten Elektronen. Die gewaltige chemische und biologische Wirkung der Elektronenstrahlung wird übrigens neuerdings und besonders augenfällig bewiesen, seitdem es COOLIDGE gelungen ist, β-Strahlen direkt durch ein Aluminiumfenster in grösseren Mengen aus einer Vakuumröhre austreten zu lassen. Es steht also der Annahme, dass die β-Strahlen zum überwiegend grössten Teil die Röntgenstrahlenwirkung bedingen, absolut nichts im Wege.

Die oben besprochenen Versuche sind eigentlich im Hinblick auf die Frage der physikalischen Sensibilisierung unternommen worden. Wenn wir die Literatur betrachten, so fallen sofort zwei grosse gegensätzliche Gruppen von Arbeiten auf. Auf der einen Seite sehen wir keine oder geringe Erfolge bei Tierexperimenten und klinischen Beobachtungen. (SALZMANN, STEPP & CERMAK, ROHRER, LENK, ULRICH, SPIESS & VOLZ, GUDZENT, BESSUNGER, HALBERSTÄDTER & SIMONS, HOLTHUSEN, FRIEDRICH & BENDER, GROSSMANN), auf der anderen Seite haben wir die gewaltigen Wirkungen der Sensibilisatoren auf die Bakterien. (Oben angeführte Autoren und neuerdings HOLTHUSEN, der meine Resultate bestätigen konnte). In der Wirkung zwischen diesen beiden Gruppen stehen die Resultate der Sensibilisierung mit Thoriumnitrat und vermittels der Metalliontophorese (ELLINGER sowie WINTZ und GHILARDUCCI). Nach den obigen Versuchen ist diese äussert grosse Diskrepanz wohl erklärlich. Da die im Gewebe ausgelösten β-Strahlen geringe Geschwindigkeit haben, spielt, wegen des kleinen Wirkungsradius, die Dicke und die Art des Zwischenmediums zwischen dem Sekundärsstrahler und dem radiosensiblen Teil des Gewebes oder der Zelle (Membran, Kern) eine ausschlaggebende Rolle. Wenn es also nicht gelingt den Sensibilisator an den stahlenempfindlichen Teil der Zelle selbst zu bringen, so dürfte es aus-

sichtslos sein auf rein physikalischem Wege eine Dosiserhöhung erreichen zu wollen, die praktisch verwertbar wäre.

Nachdem nun aus atomtheoretischen Gründen das Auftreten von freien Elektronen in dem von Röntgenstrahlen getroffenen Gewebe feststeht, nachdem im biologischen Experiment bewiesen ist, dass durch sekundäre Elektronenstrahlung die Primärstrahlenwirkung bedeutend verstärkt werden kann, und nachdem die grösste Wahrscheinlichkeit besteht, dass auch das bei der Primärbestrahlung letzten Endes wirksame Agens die sekundären β-Strahlen sind, tritt die weitere Frage auf, wie diese freien Elektronen weiterhin zur biologischen Wirkung gelangen. Wenn, wie in unsern Prodigiosusversuchen, die Elektronenstrahlung allein wirksam ist, während die Wellenstrahlen keinen Effekt haben, so ist anzunehmen, dass bei ersteren der Grund für ihre Wirksamkeit in Eigenschaften liegt, die der Wellenstrahlung nicht zukommen. Diese Eigenschaften aber sind: 1. Sie haben eine Masse, 2. sie können ihre Energie in beliebigen Teilbeträgen an die Umgebung abgeben, 3. sie haben eine Ladung. Die Bewegungsenergie d. h. das $\frac{mv^2}{2}$ des Elektrons wird wohl dazu verwendet werden, um weitere Elektronen aus dem Atomverbande herauszuschleudern, um zu jonisieren, oder um das System zu erwärmen. Fassen wir aber die Tatsache der Ladung näher ins Auge, so ist es naheliegend an eine Veränderung der elektrischen Verhältnisse in der Zelle zu denken. Sie kann betreffen die kolloidalen Teilchen oder die Phasengrenzen und Membranen (Bordier, Wels, Ferneau & Pauli, Brummer). Diese Veränderung der Membranen ist zu denken als eine Ladungsverschiebung auf dieselben und zwar vorerst in negativem oder in positivem Sinne. Wenn aber eine solche Ladungsänderung tatsächlich zustande kommt, so muss dadurch auch eine Permeabilitätsänderung der Membran eintreten. Ich habe deshalb im Jahre 1922 diesbezügliche Untersuchungen an Spirogyrazellen und Froschmuskeln vorgenommen. Die ersteren prüfte ich auf ihre Durchlässigkeit für Strychninnitrat, die letzteren für Wasser, habe aber gegenüber den unbestrahlten Kontrollen keine Ausschläge erhalten. Offenbar war die Methode zu grob. Trotzdem haben Steiger und *ich* 1923 die Möglichkeit der Membranwirkung der Röntgenstrahlen hervorgehoben. Es ist dann Holthusen gelungen durch sehr hohe Röntgendosen Hämolysebeschleunigung herbeizuführen. Ebenso sprechen die Versuche von Schmidt, Cramer, Straub & Meyer, Brummer, Lieber für eine Durchlässigkeitsänderung bei Bestrahlung.

Wie gesagt, muss jede lokalisierte Ladungsänderung nicht nur eine Änderung der Permeabilität der Zellgrenzflächen, sondern auch

der dort vorkommenden Potentiale zur Folge haben. Die in der lebenden Zelle vorkommenden Potentiale sind aber aller Wahrscheinlichkeit nach:

1. Adsorptions-, 2. Diffusions-, 3. Phasengrenz-, 4. Membranpotentiale. Zur Klärung der Frage, ob dieselben unter Bestrahlung eine Veränderung erleiden, wurden stromgebende Ketten exponiert und deren Potentialdifferenz vor, während und nach der Bestrahlung verfolgt. Kurz zusammengefasst ergaben sich folgende Resultate: 1. Wird eine Phasengrenzkette der Bestrahlung ausgesetzt, so steigt deren Potentialdifferenz sofort um 1,5 bis 4, 0 mV an, um sofort nach der Unterbrechung des Strahleneinflusses auf den normalen Wert abzusinken. Untersucht wurde NaCl gegen Dimethylanilin-HCl einerseits und Natriumoleat andrerseits sowohl in Guajakol als auch in o-Toluidin.

2. Die CREMER'sche Glaskette verhält sich genau gleich, die Potentialunterschiede betragen dabei 2,5 bis 5,5 mV.

3. Eine Konzentrationskette mit freier Diffusion von konz. HCl gegen m/500 HCl ergab keinen sichern Ausschlag.

4. Die EMK beim DONNAN-Gleichgewicht durch eine nicht ausgetrocknete Kollodiummembran wurde nicht verändert.

5. Die Spannung, die zu beiden Seiten einer Ferrocyankupfermembran auftritt, wurde nicht beeinflusst. (Ableitung über gesättigte Kalomelelektroden zur Kompensationsschaltung, Fehler 0,15 bis 0,30.) Biochem. Z'schr. 171.240, 1926.

Zur Erklärung des feinern Mechanismus dieser Röntgenstrahlenwirkung ist die von MICHAELIS neuerdings gegebene Siebtheorie der semipermeablen Membranen geeignet. Nach dieser Theorie ist die Durchlässigkeit für bestimmte Stoffe nicht nur abhängig von der Porengrösse oder besser von dem Verhältnis derselben zum Teilchendurchmesser des permeierenden Stoffes, sondern auch von der elektrischen Ladung der Membran. Die Membranladung hat nur auf die geladenen Teilchen, auf die Jonen, einen Einfluss, und zwar einen umso grössern, je kleiner die Poren sind, weil offenbar nur die wandständigen Teilchen erheblich elektrisch beeinflusst werden. Es ist bekannt, dass im allgemeinen die Membranen durch Jonen umgeladen werden können. Diese Umladung lässt sich direkt aus der Veränderung der Potentiale, die bei der Diffusion durch die Membran auftreten, erschliessen. Die Membranladung wirkt dann ähnlich wie die Gitterladung im Elektronenrohr, sie steuert den Durchtritt der Jonen. Es ist nun wohl denkbar, dass nicht nur durch Jonen sondern auch durch Elektronen eine Ladungsänderung in negativem Sinne zustande kommen kann. Diese Negativierung würde dann die Kationen beschleunigen und die Anionen verzögern so, dass nach der NERNST'schen Formel die EMK erhöht würde. Aus dem gesagten geht hervor, dass eventuell bei Membranen mit grossen Poren die Potentialänderung zu gering ist um nachweisbar zu sein. MICHAELIS hat aber nachgewiesen, dass die nicht ausgetrocknete

Kollodiummembran und die Ferrocyankupfermembran, die mir keinen Ausschlag gegeben haben, grosse Poren haben. Dagegen gibt das Glas sehr feinporige Membranen. Bei der CREMER'schen Glaskette habe ich aber auch die grössten Ausschläge, bis zu 5,5mV, erhalten. Die Oele sind in diesem Sinne meines Wissens noch nicht studiert; ich lasse deshalb meine Befunde an Oelketten in diesem Zusammenhange weg. Jedenfalls spielt aber auch dort ein ähnlicher Mechanismus mit.

Nach obiger Theorie sollte also nach Bestrahlung die Membrandurchlässigkeit für Kationen erhöht, für Anionen erniedrigt sein. Das letztere hat BRUMMER für OH-Ionen direkt nachgewiesen. Für die Erhöhung der Durchlässigkeit für H-Ionen sprechen auch meine Versuche über p_H-Änderungen im subcutanen Gewebssaft (Kl. W'schr. Oktober 1926). Nachdem durch die Arbeiten von DENIS, MARTIN, ALDRICH, GOLDEN, MAHNERT & ZACHERL, HUSSEY, HOLTHUSEN, CLUZET & KOFMAN, KONRICH & SCHELLER, KROETZ, GIGON, KOLTA & FÖRSTER eine Reaktionsänderung im Blute im Sinne einer vorübergehenden Frühacidose und einer darauffolgenden, länger andauernden, Spätalkalose feststeht, habe ich mit der Subcutanelektrode von SCHADE, NEUKIRT & HALPERT intra vitam die H-Ionenconcentration des subcutanen Gewebssaftes in ihrer Abhängigkeit von der Röntgenbestrahlung verfolgt und dabei folgendes gefunden: Die Wasserstoffionenconcentration der Subcutis wird deutlich nach der sauren Seite hin verschoben. Dieser Effekt erscheint schon 2 bis 3 Stunden nach Einwirkung der Strahlen. Normale p_H-Werte treten erst nach ca. 6 Tagen wieder ein. Diese Versuche sprechen mit denjenigen am Blute für einen vermehrten Einstrom von sauren Körpern oder H-Ionen von den betroffenen Zellen her ins Blut. Dieser vermehrte Einstrom lässt sich aber sehr gut durch die oben erörterte erhöhte Durchlässigkeit der primärbetroffenen Zellmembranen erklären.

Auch die Versuche SCHNEIDERS lassen sich mit der Permeabilitätstheorie erklären. Dieser Autor fand, dass Paramäcien gegen eine p_H-Verschiebung ihres Milieus nach der sauren Seite hin bis zu einem p_H von 3,2 sehr resistent sind. Eine Röntgenstrahlenwirkung lässt sich in diesem Bereiche im Sinne einer Schädigungsvergrösserung nicht nachweisen. (Ob vielleicht im Grenzbereich von $p_H = 3{,}2$ das Gegenteil, eine Schädigungsverminderung beobachtet wird. darüber macht der Autor keine Angaben.) Im Gegensatz dazu werden die Tiere durch eine Reaktionsverschiebung nach der alkalischen Seite rasch geschädigt (Quellung, Tod.) Und zwar ist es auch gelungen diese Schädigung durch Röntgenbestrahlung bedeutend zu erhöhen. Diese Tatsache könnte auch darauf zurückgeführt werden, dass durch negative OH-Ionen die Membran der Paramäcienzelle im gleichen Sinne

umgeladen wird, wie durch negative Elektronen. Im sauren Bereiche aber wirken β-Strahlen entgegen gesetzt wie positive H-Ionen. Wenn die letzte Wirkung auch nicht nachweisbar sein sollte, so wäre es möglich, dass die Elektronenwirkung durch die Elektrolytwirkung übertönt würde. Wahrscheinlich ist in diesem Falle für die Röntgenwirkung auf die Einzelzelle nicht eine Veränderung des Milieus — jedenfalls nicht allein — massgebend, sondern eine Beeinflussung der gegenseitigen Wechselbeziehungen zwischen Zelle und ihrer Umgebung. Das auf andere Weise veränderte Milieu (Elektrolytkonzentration) lässt nur die Strahlenwirkung mehr oder weniger augenfällig manifest werden.

Nach dem heutigen Stande der strahlenbiologischen Forschung steht die ausschlaggebende Bedeutung der Elektronenstrahlung für die Röntgenstrahlenwirkung fest. Eine Veränderung der Membranpermeabilität durch dieselben liegt aus theoretischen Gründen nahe und wird mannigfach durch Experimente gestützt.

ZUSAMMENFASSUNG

1) Aus Versuchen über Sekundärstrahlung von blanken und kolloiden Metallen auf Prodigiosus, Kaninchenhaut und Kaninchenhoden geht hervor dass,

a) durch Sekundärstrahlenwirkung keine Dosiserhöhung zu erwarten ist, die praktisch verwendbar wäre, und dass

b) die sekundären β-Strahlen für die Röntgenstrahlenwirkung von ausschlaggebender Bedeutung sind.

2) Diese Tatsache legt eine Membranwirkung der Röntgenstrahlen nahe. Diese Annahme wird unter andern durch Versuche an stromgebenden Ketten gestützt, die ergaben, dass durch Röntgenbestrahlung die Potentialdifferenzen von Öl- und Glasketten erhöht werden, während die E. M. K. bei freier Diffusion in Wasser, bei Ferrocyankupfer- und nicht ausgetrockneter Kollodiummembran unbeeinflusst bleibt.

3) Die H-Ionenkonzentration der subkutanen Gewebssäfte nimmt nach Röntgenbestrahlung zu. Dies stimmt theoretisch mit der von MICHAELIS gegebenen Siebtheorie der semipermeablen Membranen überein, wonach durch negative Aufladung der Zellgrenzen ihre Durchlässigkeit für Kationen erhöht sein muss.

SUMMARY

1) By experiments with secondary rays from bright and colloid metals on Prodigiosus, skin and testicles of rabbit it has been found:

a) that no increase of dosage of any practical value is to be expected from the secondary rays and

b) that the secondary β-rays are of decisive importance for the efficacy of the röntgen-rays.

2) This condition makes a membrane effect of the röntgen-rays likely. This assumption is supported, among others, by experiments on current-producing chains, which showed that by exposure to röntgen-rays the potential

difference between oil- and glasschains is increased, while the E. M. F. is unaffected by free diffusion in water, by a membrane of copper-ferrocyanide and a non-desiccated collodion membrane.

3) The concentration of the H-ions in the subcutaneous tissue-fluid becomes increased after exposure to röntgen-rays. Theoretically this agrees with the filter-theory of Michaelis concerning the semi-permeable membranes, according to which their permeability for cathode-ions must become increased through negative charge of the cell-limits.

RÉSUMÉ

1) Des expériences au sujet du rayonnement secondaire des métaux, polis ou colloïdaux, sur le prodigiosus, l'épiderme ou les testicules de lapin ont montré que:

a) les rayons secondaires ne causent pas une augmentation des doses qui serait applicable en pratique,

b) les β rayons secondaires jouent un rôle prépondérant dans l'action des rayons Röntgen.

2) Ce fait indique une influence des rayons Röntgen sur les membranes. Cette hypothèse est justifiée par des expériences avec des piles, donnant un courant. Les différences de potentiel dans les piles huileuses ou à verre augmentent sous l'action des rayons Röntgen, tandis que la force électromotrice n'est pas influée en cas d'une diffusion libre dans l'eau à travers d'une membrane de cyanure de fer et de cuivre ou de collodion pas desséché.

3) La concentration des ions H dans les humeurs des tissus subcutanes augmente sous l'influence des rayons Röntgen. Cette observation est bien d'accord avec la théorie de Michaelis, qui présume une filtration à travers des membranes semiperméables, suivant laquelle la perméabilité des diaphragmes cellulaires aux cat-ions doit accroître à cause d'un chargement négatif.

AUS DER GYN. ABT. (CHEFARZT DR. PAUL JUNG) UND DEM CHIR.-GYN. RÖNTGENINSTITUT (VORSTAND DR A. SCHIRMER) DES KANTONSSPITALS ST. GALLEN

ÜBER DIE KOMBINATION DES PNEUMOPERITONEALEN RÖNTGENBILDES DER WEIBLICHEN KLEINBECKENORGANE MIT DER HYSTEROSALPINGOGRAPHIE

von

Paul Jung und *A. Schirmer*

(Tabulæ XXIX—XXXIV)

Die Röntgenaufnahme der weiblichen Kleinbeckenorgane vermittelst des Pneumoperitoneums hat in der Gynäkologie bis jetzt nur wenig Eingang gefunden. Selbst der wertvolle, vollendet ausgestattete Atlas von Wintz-Dyroff scheint ihre Verbreitung in Fachkreisen kaum gefördert zu haben. Wenigstens verlautet in der jüngsten gynäkol. und radiol. Fachliteratur nicht sehr viel davon.[1] Die Gründe dafür dürften ziemlich nahe liegen. Einmal entbehren viele Frauenkliniken heute noch einer diagnostischen Röntgenapparatur. Zu der in einem zentralen Institut oder in einer Schwesterklinik untergebrachten ist aber der Weg zu umständlich und zeitraubend. Das allein schon kompliziert für Manchen die Verwendung derart, dass er meist lieber auf das Verfahren verzichtet. Dieser Verzicht fällt um so leichter angesichts der sonst hoch entwickelten gyn. Diagnostik. Kommen noch dazu Anfangsschwierigkeiten in der richtigen Interpretation, die Notwendigkeit, das Bild erst lesen zu lernen; vielleicht auch die Manchem etwas kompliziert scheinende Herstellungstechnik. Also Veranlassung genug, um mindestens zum neuen Verfahren sich indifferent zu stellen. Auch wer sich über längere Zeit wie wir systematisch damit befasst, sieht sich immer wieder neuen Schwierigkeiten, Täuschungen und Irrtümern in der Deutung gegenüber. Zur Erlangung möglichster Sicherheit in der richtigen Bewertung der Aufnahmen haben wir von Anfang an in erster Linie Fälle ausgewählt, welche ohnehin zur Operation vorgesehen waren, um so die bioptische Kontrolle unmittelbar anschliessen zu können. Anhand des Tastbefundes wurde gemeinsam die Erklärung des Bildes mit Stift und Beschreibung niedergelegt und darauf bei der Operation in situ nachgeprüft.

[1] Von der neuesten Mitteilung Dyroffs in der Deutschen Röntgengesellschaft erhielten wir erst Kenntnis als diese Arbeit bereits in Druck gegangen war. Es konnte deshalb darauf auch nicht mehr Bezug genommen werden.

Dieses Vorgehen vermochte uns wertvolle Fingerzeige zu geben, so dass wir anhand von ca. 150 Aufnahmen uns eine gewisse Übung in ihrer Aufschliessung zusprechen dürfen. Und trotzdem ist gerade dort, wo eine Ergänzung unserer sonstigen Diagnostik am ehesten erwünscht wäre, wie z. B. bei den entzündlichen Tubo-Ovarialtumoren etc. mit ihren Beziehungen zur Nachbarschaft die Differenzierung des einfachen pneumoperitonealen Bildes oft sehr erschwert, das Verlangen nach ihrer Erleichterung somit durchaus gerechtfertigt.

Die Pertubation zur diagnostischen Erkundung der Tubendurchlässigkeit hat bald den Wunsch gezeitigt, anstelle der blossen Durchblasung die Füllung mit einem Kontrastmittel zu verwenden, was erlaubte, das Resultat auf dem Röntgenfilm zu fixieren. Ursprünglich von Kennedy lediglich zum Zweck der Tubenpermeabilitätsprüfung angegeben, ist diese Salpingo- bezw. Hysterosalpingographie später in Deutschland besonders von Schober aufgenommen worden. Beide Autoren verwendeten als Kontrastmittel Bromnatrium; E. Williams und R. Reynolds später Wismuth oder Bariumsulfat-Emulsion. Wir selbst sind dann in der Folge zum Lipiodol übergegangen. Das Primum non nocere verlangte auch hier zuvor die Entscheidung zweier Fragen: nach der Möglichkeit einer Keimverschleppung in Tube und Peritonealraum einerseits und der entzündlichen Schädigung von Serosa und Tubenschleimhaut anderseits. Auch Schober weist ausdrücklich auf diesen Punkt hin. Wir haben deshalb zunächst das Verfahren nur bei Tuben verwendet, deren operative Entfernung ohnehin bevorstand. So bot sich uns Gelegenheit, jeweilen nach Eröffnung des Abdomens durch Auswischen des kleinen Beckens mit Secretpinsel Proben zur kulturellen Sterilitätsprüfung des Peritonealraums zu entnehmen und ferner an den exstirpierten Tuben überdies ebenfalls eine bakteriologische Kontrolle auf Keimanwesenheit vorzunehmen. Aber auch die Frage nach Setzung eines entzündlichen Reizes der Tubenschleimhaut durch das Kontrastmittel konnte so einer histologischen Entscheidung nähergebracht werden. Es ist klar, dass zur einwandfreien Überprüfung mit der Operation verschieden lange zugewartet werden musste, um so einer eventl. entzündlichen Reaktion die nötige Zeit zu lassen. Die bakteriologisch-histologischen Untersuchungen hatte Prof. Helly im Pathologischen Institut des Kantonsspitals die dankenswerte Freundlichkeit zu übernehmen. Sie hatten das erfreuliche Resultat, dass in keinem unserer Fälle jemals weder eine Keimverschleppung in Tube oder Peritonealraum, noch auch eine entzündliche Reaktion der Tubenschleimhaut nachgewiesen werden konnte. So weit allerdings wie Heuser, der Lipiodol zur Schwangerschaftsdiagnose verwendete, ohne Abort zu provozieren(!) möchten wir selbstverständlich in der Schätzung seiner Harmlosigkeit

nicht gehen. Aber auch klinisch vermissten wir die kolikartigen Schmerzen »als zwar rasch abklingende Reizerscheinungen des Peritoneums« wie sie SCHOBER sah und wie wir sie selbst bei der Verwendung von Bromnatrium regelmässig beobachteten. Mit Ausnahme eines einzigen Falles, wo leicht ziehende Schmerzen nach der Seite vermerkt sind, verlief die Durchleitung des Lipiodols durch Uterus und Tuben überhaupt ohne irgendwelche Äusserung einer unangenehmen Empfindung seitens der Patientin. Das kann ausser in der verschiedenen Beschaffenheit der Kontrastmittel auch in der Technik ihrer Einverleibung begründet sein. Sie weicht insofern wesentlich von jener der beiden genannten Autoren ab, als wir der immer etwas komplizierten Verwendung eines besondern Gebläses entraten zu können glaubten. Mit der einfachen Braun'schen 2 ccm Intrauterin-Spritze liess sich dasselbe viel einfacher erreichen. Ihre Einführung geschieht ohne vorausgegangene Dilatation unter Kontrolle des Auges in irgend einem der bekannten Vaginalspecula, unter den selbstverständlich peinlichsten Kautelen. Die Portio wird, wie gewohnt, vor Einführung der Spritze in der Umgebung des äussern Muttermundes gejodet. Dass es so gelingt, vom Cavum uteri aus Flüssigkeiten nach den Tuben zu verbringen, ist längst bekannt; gab es doch in der Gynäkologie eine Zeit, wo sogar von sehr berufener Seite aus vorgeschlagen wurde, auf diese Weise gonorrhoische Pyosalpingitiden anzugehen. Die nötige Menge Kontrastmittel lässt sich bei unserem Vorgehen so erheblich einschränken, da wir mit 2 ccm auskommen, währenddem SCHOBER z. B. von 10 ccm spricht. Das ist nicht zu verwundern, denn bei Verwendung eines Gebläses bleibt schon auf dem langen Weg eine reichliche Menge liegen. Die Druckmessung allerdings fällt bei unserer Methode weg, sie ist ohnehin gegenstandlos, da wir ohne jeden Druck injizieren. Die Zusammensetzung des von uns injizierten Präparates lässt die Möglichkeit einer Schleimhautschädigung kaum zu. Das Lipiodol Lafay ist ein jodiertes vegetabiles Öl, von dem 1 ccm = 0.54 gramm reines Jod enthält. Die Mischung ist dabei eine so innige, dass das Öl selber durch die Jodbeimengung seine Farbe nicht verändert und in seinem Aussehen in nichts sich von demjenigen eines gewöhnlichen vegetabilischen Öles unterscheidet. Ursprünglich lediglich therapeutisch enteral sowohl als parenteral verwendet, wurde es zuerst 1921 von SICARD und FORESTIER in die Röntgendiagnostik eingeführt. Gerade seine Reizlosigkeit auf die Schleimhaut verschaffte ihm sehr rasch ein ausgedehntes Anwendungsgebiet, speziell zur Aufnahme von Regionen, die bis anhin, vermöge ihrer empfindlichen Zartheit, der Darstellung im Röntgenbilde besondere Schwierigkeiten bereiteten (z. B. Epiduralund Subarachnoidealraum, Bronchien, Tränensackkanal, Harnwege

etc.). Das ölige Vehikel verleiht dem Präparat offenbar seine Reizlosigkeit. Was es als Kontrastmittel leistet, erhellt am besten aus den hier reproduzierten Aufnahmen selbst. Über ihre klinische Bedeutung hat SCHOBER am Wiener Gyn. Kongress 1925 sich ausgesprochen. Wir können uns hier darauf beschränken, nach unseren Erfahrungen seine Auffassung zu unterstreichen.

Nun drängte sich eigentlich der Versuch auf, durch eine *Kombination* dieser Hysterosalpingographie *mit* der Aufnahme der Kleinbeckenorgane im Pneumoperitoneum, diese einer rascheren und leichteren richtigen Interpretation näherzubringen.

Für die einfache Hystero-Salpingographie hat sich uns in Übereinstimmung mit den Angaben von FERRÉ die horizontale Rückenlage als zweckmässigste erwiesen. Wir verwenden dazu einen Tisch unter welchem die Potter-Buckyblende verschiebbar montiert ist, so dass die Einstellung des Films und der Röhre ohne weitere Lageveränderung der Patientin vorgenommen werden kann. Der mit doppeltem Verstärkungsschirm versehene Film vom Format 24 : 30 cm wird unter die Mitte des Kreuzbeins eingestellt und der Zentralstrahl der horizontal liegenden Röhre auf die Mitte zwischen Nabel und Symphyse gerichtet. Die in das Cavum uteri eingeführte Braun'sche Spritze wird während der Injektion des Lipiodols langsam bis an den innern Muttermund zurückgezogen. In diesem Augenblicke erfolgt die Aufnahme unter Verwendung einer fein zeichnenden Glühkathodenröhre, einer Röhrenspannung von 55 KV eff. und einer Belastung von 40 MA $1^{1}/_{2}$—2 Sekunden. Von grösster Wichtigkeit ist es, die Exposition unmittelbar nach der Injektion des Kontrastmittels und vor gänzlicher Entfernung der Injektionskanüle aus dem Uterus vorzunehmen, da wenige Sekunden genügen, um eine Entleerung des Cavums zufolge der einsetzenden Uteruskontraktionen zu bewirken. Wird diese Massregel nicht eingehalten, so erhalten wir nicht bloss mangelhafte Füllungsbilder des Cavums, sondern auch öfters für die Beurteilung der Tubenzeichnung störende Kontrastschattenflecke im Scheidengewölbe.

Zur Kombination der Uterus-Tubenfüllung mit dem Pneumoperitoneum wird vorerst in Rückenlage auf dem Buckytisch die Insufflation der Bauchhöhle vorgenommen und zwar mittelst Kohlensäuregas unter einem Drucke von 20—30 mm Hg in der Menge von 1 500—1 800 ccm. Darauf Einführung der Intrauterinspritze in der erwähnten Weise und nach Entfernung des Speculums sorgfältige Umdrehung der Patientin in Bauchlage. Die Injektion des Kontrastmittels unter Rückzug der Spritze bis zum innern Muttermund erfolgt unmittelbar vor der Aufnahme. Der uns zur Verfügung stehende Aufnahmetisch (siehe Abb. 1) erlaubt ohne grösseren Kräfte- und Personalaufwand

seine Hebung aus der Horizontalen um 30°, wodurch die zur Ansammlung des Gases im kleinen Becken und zum Zurückgleiten der Därme notwendige Beckenhochlagerung erzielt wird. Im Gegensatz zu Wintz und Dyroff, deren Technik der unseren im Allgemeinen entspricht, haben wir stets eine Neigung der Patientin um 30° aus der Horizontalen als genügend befunden und auf eine Steilerstellung mit Rücksicht auf die damit verbundene Unbequemlichkeit, verzichtet. Die Röhre wird sodann über die unter die Mitte zwischen Symphyse

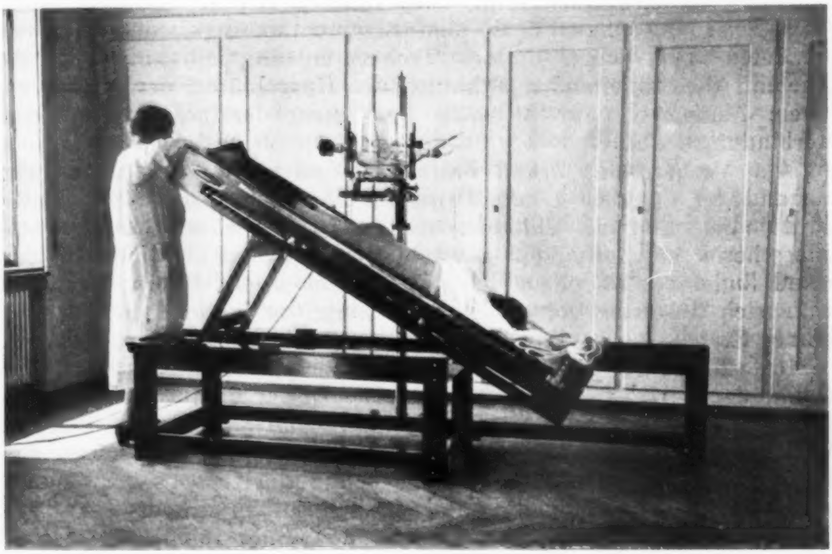

Abb. 1.

und Nabel eingestellte Kassette so zentriert, dass der Mittelstrahl durch die Spitze des Os coccygis auf die Mitte des Films vom Format 24 : 30 cm gerichtet ist. Bei der in der Regel sich ergebenden Horizontalstellung der Röhre beträgt somit der Winkel zwischen Plattenebene- und Zentralstrahl 60°. Wir erhalten dadurch das den *Anforderungen von* Wintz *und* Dyroff entsprechende minimal verzeichnete Darstellungsfeld des kleinen Beckens einwandfrei. Die Exposition geschieht unter den gleichen technischen Bedingungen wie bei der vorgängig beschriebenen Aufnahme mit blosser Uterus-Tubenfüllung ohne Pneumoperitoneum. Die durch die Verwendung der Potter-Buckyblende bedingte Verkürzung der Focus-Filmdistanz auf 70 cm haben wir nie als störend empfunden. Dass auch unter

anderen Betriebsbedingungen der Röhre und ohne Verwendung einer Bucky-Blende bei der Wahl der richtigen Strahlenqualität brauchbare Bilder hergestellt werden können, ist selbstverständlich. Eine möglichste Kürzung der Expositionszeit ist zur Vermeidung von unscharfen Aufnahmen angezeigt und Belichtungszeiten von mehr als 2 Sekunden sind deshalb nicht zu empfehlen.

Über unsere Technik der Erstellung des Pneumoperitoneums sei folgendes bemerkt. Die transabdominale Aufblähung mittelst Punktion der Bauchwand erfolgt nach unseren Erfahrungen am besten etwa zwei Querfinger über dem Ligamentum inguinale. Wir verwendeten dazu einen dünnen Trokart mit Doppelhahn, wovon der eine mit dem zuleitenden Schlauch des Gasgebläses, der andere mit einem Manometer zur Messung des intraabdominellen Druckes in Verbindung steht.

Als Vorbereitung erhält Patientin je nach Alter und Allgemeinzustand $^1/_3$, $^1/_2$ bis 1 ccm Pantopon-Scopolamin, die Einstichstelle wird jodiert und mit Chloräthylspray oder besser durch Infiltrationsanaesthesie unempfindlich gemacht. Den ersten deutlichen Widerstand findet die Nadel an der Fascie, nach seiner Überwindung hat man sich insofern vor einer Täuschung zu hüten, als nun nach kurzer Strecke nochmals ein zweites, wenn auch viel geringeres, doch nichtsdestoweniger deutliches Hindernis zu passieren ist, das Peritoneum, der paradoxe Widerstand A. Mayer's. Ist auch dieser überwunden, wird die Nadel zurückgezogen und an der unbehinderten Verschieblichkeit der Kanüle allein überzeugt man sich leicht, dass sie sich in der freien Bauchhöhle befindet. Als Gas verwendeten wir seiner Unschädlichkeit und leichten Resorbierbarkeit wegen käufliches Kohlenstoffdioxyd, das direkt aus einer Bombe übergeleitet wird. Guthmann benützte s. Zt. anstatt dessen frisch aus Marmor und Salzsäure in dem Kipp'schen Apparat entwickeltes Kohlensäureanhydrid, worin wir in Übereinstimmung mit Graff keine Verbesserung des Verfahrens, sondern eher eine unnötige und zeitraubende, für die Luft im Behandlungsraum auch keineswegs gleichgültige Komplikation zu erblicken vermögen. Der von uns verwendete Gasapparat besteht aus einer grossen mit Skala versehenen Flasche, die mit Kohlensäuregas gefüllt wird und der das Gas auf dem Wege über eine Filtrierflasche (Wasser mit Oxycyanat) entnommen wird. Zur Konstanthaltung des Gasdruckes in dem Gasbehälter und folglich zur bequemen Ablesung des Gasverbrauchs dient eine dritte Flasche, deren Wasserfüllung mit der Wasserfüllung des Gasbehälters kommuniziert und aus welcher das Wasser in den Gasbehälter mittelst einer einfachen Luftpumpe übergeführt werden kann. Der Gasdruck kann ununterbrochen genau auf derselben Höhe gehalten werden.

Zur Messung des Gasdruckes im Gasbehälter und in der Filtrierflasche dienen zwei Quecksilbermanometer, zur Messung des effektiven intraabdominellen Druckes nach der Insufflation wurde ein kleines Aneroidmanometer, eingestellt auf Quecksilber, verwendet. Die nötige Gasmenge berechnet GUTHMANN auf 200, GRAFF auf 50—100, wir bedurften dazu durchschnittlich $1^1/_2$ bis 2 Liter. Das dürfte davon herrühren, dass wir aus Gründen der Vorsicht und Schonung für die Patientin möglichst langsam mit *geringerem* Druck arbeiten, wodurch ein Teil des eingeführten Gases durch Resorption vorweg immer wieder verloren ging, sodass die Gesamtgasmenge dadurch naturgemäss grösser sein musste. Von der raschen Resorbierbarkeit konnten wir uns übrigens bei unmittelbar im Anschluss an die Einblasung angeführten Operationen durch die auffällig geringe entweichende Gasmenge überzeugen; abdomineller Bluterguss zeigte sich nie; die Einstichstelle an der Serosa war nur mit Mühe oder gar nicht auffindbar, dagegen liess sich oft eine allgemeine feine Injektion der Parietalserosa nachweisen. Aber auch sonst ist durch die Perkussion nach ca. 12 Stunden kaum mehr Gasinhalt festzustellen und meist das subjektive Gefühl der Völle verschwunden. Dies bewiesen am besten auch jene Fälle, wo wir der ersten Aufnahme nach Entwicklung des Films, die ca. 20 Minuten in Anspruch nimmt, eine zweite folgen lassen wollten, aber wegen bereits stark verminderter Blähung kein brauchbares Bild mehr erhielten. Nennenswerte Beschwerden äusserten meist nur magere Patientinnen während der maximalen Blähung, und zwar trat dabei fast regelmässig das bekannte Phrenicus-Symptom, der sog. Schulterschmerz, deutlich in Erscheinung. Fast konstant war eine erhebliche Pulsverlangsamung um 15—20 Schläge. Die Zunahme des Leibesumfangs betrug durchschnittl. 6—10 cm, die Dauer bis zur maximalen Blähung 5—10 Minuten; der aufgewendete Druck in mm Hg. gemessen 20—30 mm. Über die Steigerung des intraabdominellen Drucks haben wir exakte Messungen ausgeführt. Normalerweise wenig negativ, steigt er während der Insufflation adäquat dem aufgewandten Druck des Gebläses fast regelmässig auf 20—30 mm. Stieg er anfangs etwas höher, so kehrt er bald wieder auf diese Höhe zurück, und verweilt dabei bis kurze Zeit nach Absetzen der Gaszufuhr, um dann wieder zu sinken. Auch der Frage allfälliger Nierenschädigungen durch intraab. Drucksteigerung haben wir unsere Aufmerksamkeit geschenkt. In ca. 40 Fällen konnten trotz genauester und in regelmässigen Zeitabständen wiederholter Proben vor und nach der Blähung, nicht ein einziges Mal Spuren von Eiweiss oder Zucker nachgewiesen werden. Überhaupt waren unangenehme Zwischenfälle ernsterer Art nie zu beobachten, vor allem auch nicht die von KEHRER befürchtete Kohlensäurever-

giftung durch Resorption aus den grossen peritonealen Lymphdrüsen. Nichts destoweniger möchten wir der wiederholt vertretenen Auffassung, der Eingriff eigne sich zur Ausführung in der Sprechstunde, entschieden entgegentreten; schon aus Gründen der Vorbereitung: energische Abführkur, und nachheriger Kontrolle, behielten wir unsere mit Pneumoperitoneum kombinierten Fälle allermindestens drei Tage im Spital.

Aus einer grossen Kollektion von insgesamt 147 Aufnahmen haben wir hier einige zusammengestellt, die uns besonders instruktiv erschienen. 7 davon betreffen einfache Hystero-Salpingographien; 12 weitere deren Kombination mit dem Pneumoperitoneum. Die den Bildern beigefügten Legenden dürften über das wesentliche orientieren. Wir möchten die Aufnahmen selber sprechen lassen, glauben aber doch uns zum Schlusse berechtigt: Das Verfahren ist noch einer weitgehenden Vervollkommnung fähig und fortgesetzte Übung in der Interpretation der Bilder mag noch manche wertvolle Erkenntnis bergen. Auf jeden Fall dürfte so viel feststehen: Wenn der Röntgenaufnahme der Kleinbeckenorgane ein Bürgerrecht in der gynäkologischen Diagnostik beschieden sein soll, dann dürfte der Weg zu diesem Ziel über die Kombination der Salpingo-Hysterographie mit dem Pneumoperitoneum führen.

ZUSAMMENFASSUNG

Der bisherigen, einfachen pneumoperitonealen Aufnahme der weiblichen Kleinbeckenorgane im Röntgenbild stellten sich besondere Schwierigkeiten in der Deutung entgegen, namentlich für die Beziehungen mit den Nachbarorganen. Durch eine Kombination mit der Salpingo-Hysterographie, d. h. der Kontrastfüllung von Uterus und Tuben mittelst Lipiodol, wird besonders die Interpretation des Röntgenbildes bei Adnexaffektionen, Tubargravidität, die Differenzierung von Adhäsionen und Erkrankungen der Nachbarorgane u. s. w. wesentlich gefördert. Die Salpingohysterographie für sich allein zur Permeabilitätsprüfung der Tuben, bietet gegenüber der einfachen Tubendurchblasung den grossen Vorteil der optischen, subjektiver Täuschung weniger ausgesetzten Kontrolle vor der blossen akustischen. Sie ermöglicht aber gerade in Verbindung mit dem Pneumoperitoneum auch die Erkennung von Art und Sitz eines Hindernisses und gibt zudem besseren Aufschluss über Form und Entwicklungsgrad des Uterus. In der Diagnostik intrauteriner Veränderungen, Tumoren, Polypen, Schleimhautunregelmässigkeiten, dürfte sie im Falle sein, die komplizierte und nicht ungefährliche Aufschliessung und Austastung des Uteruscavums vollwertig zu ersetzen. Darin muss zur Zeit die Hauptbedeutung der Kombination von pneumoperitonealem Röntgenbild mit Hystero-Salpingographie für die gynäkologische Diagnostik erblickt werden. — Nachteile hat das Verfahren den Verfassern an ca. 150 Aufnahmen keine ergeben.

SUMMARY

The simple pneumoperitoneal method of taking roentgenograms of the female pelvic organs, so far employed, raises difficulties in the way of interpretation, particularly in respect of the relationship of these to neighbouring organs. By combining this method with that of salpingo-hysterography, that is to say the filling up of the uterus and tubes with some opaque substance, such as lipiodol, the interpretation of roentgenograms is much facilitated, particularly in cases of affections of the adnexa, tubal gravidity, as well as in the differentiation from adhesions and diseased conditions in neighbouring organs etc. Salpingo-hysterography alone for testing the patency of the tubes has the great advantage over simple tubal inflation of being an optic method and thus less liable to subjective misconceptions than the mere acustic one. But just in connexion with pneumoperitoneum it enables one to learn something of the nature and location of the obstruction, in addition to giving better information as regards shape and degree of development of the uterus. In the diagnosis of intrauterine changes, tumours, polypi, irregularities in the mucous membrane, they are quite able to fully replace the not harmless method of dilatation and palpation. It is in this respect that the combined methods of pneumoperitoneal roentgenograms and salpingo-hysterography will in future find their main usefulness for gynecological diagnosis. — The authors have had no aftereffects from the procedure in about 150 cases.

RÉSUMÉ

Les radiographies exclusivement pneumo-péritonéales faites jusqu'ici des organes du petit bassin chez la femme présentaient, au point de vue de leur interprétation, certaines difficultés, notamment en ce qui concerne leurs rapports respectifs avec les organes voisins. Une combinaison avec l'hystéro-salpingographie, c. à. d. par le remplissage de contraste de l'utérus et de la trompe avec du lipiodol, facilite grandement l'interprétation des radiographies que l'on obtient dans les affections annexielles, la gravidité tubaire ainsi que la différenciation des adhérences ou lésions des organes voisins, etc. La salpingo-hystérographie à elle seule, et comme procédé de diagnostic de la perméabilité tubaire présente par rapport à l'insufflation simple de la trompe le grand avantage d'un contrôle optique, moins exposé à une illusion subjective que le contrôle uniquement auditif. Combinée à la radiographie pneumo-péritonéale, l'hystéro-salpingographie permet de reconnaître la nature et le siège d'un obstacle quelconque et donne les renseignements les plus précis sur la forme et le degré de développement de l'utérus. Dans le diagnostic de lésions intra-utérines, tumeurs, polypes ou affections endométritiques, l'hystéro-salpingographie peut remplacer avantageusement l'ouverture et la mensuration du cavum utérin qui sont loin d'être sans dangers et d'une technique compliquée. Ainsi se manifeste la signification capitale que présente pour le diagnostic gynécologique la combinaison de la radiographie pneumo-péritonéale avec l'hystéro-salpingographie. Sur le nombre d'environ 150 cas qu'ils ont observés, les auteurs n'ont constaté aucun inconvénient imputable à la méthode.

FIGURENERKLÄRUNG

Fig. 1. *J. N. 48/1926. R. N. 3249. Collum-Ca. im Beginn.* (Im Röntgenbild nicht ersichtlich).

Uteruscavum von scharfer Dreieckform. Die linke Tube stark geschlängelt, permeabel. Rechte Tube nur in ihrem Anfangsteil unscharf erkennbar. Ihre histologische Untersuchung ergibt chronisch entzündliche Schwielenbildung mit Obliteration der lateralen beiden Drittel.

Fig. 2. *J. N. 75/1926. R. N. 3294. Sterilität infolge genitaler Hypoplasie.* Auffällig kleiner, schlanker Uterus. Die Spitze der Spritze im rechten Horn deutlich erkennbar, wodurch dessen gabelförmiges Vorspringen bedingt ist. Beide Tuben permeabel, lassen das Ausfliessen des Kontrastmittels erkennen.

Fig. 3. *J. N. 26/1926. R. N. 3187. Submucöses Myom.* Anstatt der charakteristischen Dreieckform des Cavums, zeigt dasselbe eine kolbige Auftreibung, in welche von der Gegend der lk. Tubenecke ausgehend eine Aussparung hineinragt, die einem submucösen Myomknoten entspricht. — Durch Operation bestätigt.

Fig. 4. *Ambul. R. N. 3248.* Permeabilitätsprüfung der Tuben, die beiderseits stark gewunden und lang ausgezogen erscheinen und das Ausfliessen des Kontrastmittels deutlich erkennen lassen. Uteruscavum infolge vorzeitigen Rückzugs der Spritze nicht gefüllt.

Fig. 5. *J. N. 33/1926. R. N. 3211. Retroflexio uteri.* Anstatt der Dreieckform bildet das Cavum uteri ein schmales Queroval. Zufolge der Rückwärtsverlagerung des Corpus ist dieses nicht in seiner Flächenprojektion sondern nur im Teilausschnitt einer sagittalen Ebene getroffen.

Fig. 6. *Ambul. R. N. 3408. Sterilität. Retroflexio uteri, Permeabilitätsprüfung.* Auch hier wie bei Nr. 5 anstatt der Dreieckform anstelle des Cavums eine schmale Querspalte, durch die Rückwärtsverlagerung bedingt. Beide Tuben permeabel, stark geschlängelt, mit Ausweitungen in den distalen Partien besonders links. Der Ausfluss des Kontrastmittels deutlich.

Fig. 7. *J. N. 161/1926. R. N. 3233. Beidseitg. chron. Adnexerkrankung.* Das Cavum mangelhaft gefüllt zufolge vorzeitigen Rückzugs der Spritze. Beide Tuben geschlängelt, weit ausgezogen, ihre Enden gegen den Uterus hinaufgeschlagen.

Fig. 8. *J. N. 112/1926. R. N. 3374. Mobile Retroflexio uteri.* Sie ist deutlich gekennzeichnet durch den Knickungswinkel am inneren Muttermund, bis zu welchem die Spritze zurückgezogen ist. Der Uterus scheint infolge der Retroflexion vergrössert. Die rechte Tube kontrastgefüllt, mit Ovar und Ligam. rotundum sehr deutlich erkennbar. Die linke Tube nur in ihrem uterinen Drittel kontrastgefüllt zu erkennen. In ihrem weiteren Verlauf ist nur deren Weichteilschatten wie bei der blossen pneumoperitonealen Aufnahme ohne Hysterographie zu erkennen, ebenso das unveränderte Ovar.

Während bei der einfachen Hysterographie (vergleiche Bilder 5 und 6) der retroflektierte Uterus nur im Teilausschnitt als Querspalte erscheint, ist hier zufolge der Steillage bei der Aufnahme mit entsprechender Einstellung die typische Dreieckform des Cavums gewahrt.

Fig. 9. *J. N. 84/1926 R. N. 3321. Beidseitg. chron. Salpingitis.* Scharfe Dreieckform des Uterus. Die rechte Tube geht ziemlich spitzwinklig vom Uterus ab und verläuft gewunden, hinter ihr das nicht vergrösserte Ovar, in seinem medianen Drittel vom Uterus überlagert. Die linke Tube geradegestreckt, was auf eine Fixation ihres Fimbrienendes hindeutet, in ihrem ganzen Verlauf permeabel, aber mit verschiedener Dichte, etwa in der Mitte ist die Füllung nurmehr angedeutet.

Operationsbefund: Die linke Tube auffällig stark ausgezogen, am Lig. inf. pelv., dem Sigma und dem Ovar durch schleierförmige Adhäsionen fixiert. Die Tube ist 10 cm lang und zeigt im Bereich des Isthmus eine kleinkirschkerngrosse, derbe Knötchenbildung, welche der eingeführten Sonde ein Hindernis entgegenstellt. In der Mesosalpinx ein mächtig gestautes Venenpaket. Der Schatten ist auch im Bilde deutlich erkennbar in Form eines von der rechten Uteruskante, parallel verlaufenden etwas gewundenen Weichteilschattenbandes. Seine Interpretation wurde erst bioptisch bei der Operation möglich. Auch im Bereich der rechten Tube deutliche Knötchenbildung. Das Fimbrienende aber vollständig frei. Beide Ovarien ohne Veränderung.

Fig. 10. *J. N. 104/1926. R. N. 3346. Linksseitige Follikel-Corpusluteumcyste. Doppelseitige chronische Salpingitis.* Das Cavum uteri lässt die scharfe Dreieckform vermissen. Die Aussenfläche des Fundus zeigt überall Kontrastauflagerungen, die zunächst schwer zu deuten scheinen. Die linke Tube, in ganzer Ausdehnung erkennbar, in ihrer Mitte spitzwinklig abgeknickt, das Fimbrienende angelagert an einen ziemlich scharf begrenzten, überall in Adhäsionen eingebetteten Tumor. Die rechte Tube ist stark erweitert, zunächst starr und gerade verlaufend, ihr distales Ende nicht scharf erkennbar, offenbar sich in Adhäsionen verlierend.

Bioptische Kontrolle: Sämtliche Kleinbeckenorgane in dichte Adhäsionen eingebettet, die sich über die ganze Hinterwand des Uterus und den Fundus ausbreiten. Die rechte Tube ist kleinfingerdick, zuerst ziemlich gerade vom Uterushorn entspringend, nach hinten umgeschlagen und durch eine breite Adhäsion am Mesosigma und auf der Rückwand des Uterus fixiert, das Ovar nicht vergrössert, eher klein und scirrhotisch. Die linke Tube zieht in einem scharfen spitzwinkligen Bogen nach hinten und ist ganz in Adhäsionen eingebettet. Sie geht über auf einen, dem linken Ovar entsprechenden mittelapfelgrossen, cystischen, anscheinend mehrkammrigen Tumor. Tube und Ovar zusammen. sind aufs innigste mit der Kleinbeckenserosa und dem Sigma verwachsen. Dieses reiche Netz von Adhäsionen erklärt die eigentümliche Form des Uterus im Bilde, offenbar hat sich das Kontrastmittel beim Ausfliessen aus der Tube in den Taschen und Nischen der Adhäsionsschleier verfangen.

Fig. 11. *J. N. 12/1926. R. N. 3185. Psychogen bedingte Abdominalbeschwerden. Rechtsseitg. Follikelcyste.* Der Uterus stark nach links verlagert, das Cavum mangelhaft gefüllt infolge vorzeitigen Spritzenrückzugs, Dreieckform unscharf. Aus dem Cervikalkanal fliesst das Kontrastmittel zurück. Die rechte Tube sehr lang ausgezogen in ihrem distalen Drittel mehrere Ausweitungen zeigend. Das rechte Ovar cystisch vergrössert. Die linke Tube deutlich verknäuelt, stellenweise ausgeweitet und mit dem Fimbrienende an die Uteruskante zurückverlagert.

Fig. 12. *J. N. 110/1926. R. N. 3363. Linksseitg. teratoide Dermoidcyste mit intrauterinen Abortresten.* Der retrovertierte Uterus vergrössert, entsprechend etwa einer Gravidität von 5 Wochen. Die rechten Adnexe ohne auffällige Veränderung, kein deutlicher Kontrastschatten in der rechten Tube. Verzerrte Dreieckform des Cavums, exzentrisch nach links verschoben, mit gelockerten Innenwandkonturen. Die breite Dreieckbasis wird überschnitten von dem glatt-wandigen linken Adnextumor, der ziemlich breitbasig vom linken Horn zu entspringen scheint. Bioptische Kontrolle: Der beschriebene Tumor geht gut mannsfaustgross vom linken Ovar aus, der Uteruskörper repräsentiert einen plumpen dünnwandigen Sack mit Deziduaresten.

Fig. 13. *J. N. 139/1926. R. N. 3406. Rupturierte linksseitg. Tubargravidität.* Das Uterusdreieck nach links verzogen, zeigt deutlich die im Cavum während der Aufnahme belassene Spritze. Die rechte Tube ziemlich gerade gestreckt, scharf kontrastgefüllt und bis zum Fimbrienende permeabel. Die linke Tube weniger deutlich, aber doch im Bereich der uterinen Hälfte erkennbar, verliert sich dann in einen unscharfen Tumor mit zahlreichen Adhäsionen, namentlich gegen das Sigma hin. Das Ovar links ist nicht erkennbar, wohl aber das rechte.

Bioptischer Befund: Linksseitige dem äussern Drittel angehörige Tubargravidität, mit Sigma und Kleinbeckenserosa fest verfilzt, und das linke Ovar gänzlich einhüllend. Das über faustgrosse, zum Teil organisierte Coagulum reicht bis über die Medianlinie hinüber auch das rechte Ovar umschliessend, das damit innig verfilzt erscheint. Die verschiedene Kontrastdichte erklärt sich aus dem ungleich dichten Maschenwerk der Blutgerinnsel.

Fig. 14. *J. N. 140/1926. R. N. 3416. Rechtsseitg. Tubargravidität.* Scharfe Dreieckform des Uterus, linke Tube deutlich geschlängelt. Rechts ist von einer Tube gar nichts zu erkennen, das rechte Horn geht direkt über in einen unscharfen, vielfach ausgefransten und fetzig erscheinenden Tumor, der nach unseren bisherigen Erfahrungen sehr wohl für einen Bluterguss in Anspruch genommen werden kann. Auch das Ovar ist in der Tumormasse aufgegangen, doch hat man den Eindruck, als hebe es sich mitten aus derselben schärfer ab. Vom lateralen Tumorende geht eine anscheinend torquierte Schleife, in der Richtung nach dem Coecum verlaufend, ab, über deren Deutung (Darmschlinge?) keine Sicherheit besteht.

Bioptische Kontrolle: Der Uterus physiologisch gelagert, kaum vergrössert, davor und seitlich nach rechts flüssiges Blut. Die linken Adnexe intakt, von physiologischer Grösse, Tube und Ovar gänzlich frei. Rechts stellt die Tube einen gut daumendicken Tumorsack dar, über welchen fest fixiert, quer die Appendix verläuft. Medianwärts ist eine Dünndarmschlinge ebenfalls an das gravide Horn fixiert, die ganze Masse ist in dünnflüssiges und fest geronnenes Blut eingehüllt und mit der Kleinbeckenserosa teils lose verklebt, teils fest verwachsen.

Fig. 15. *J. N. 301/1926. R. N. 3693. Kontrollaufnahme 5 Jahre nach Operation wegen linksseitg. rupt. Tubargravidität.* Das Cavumdreieck ist nur nach oben und rechts scharf, nach links ausgefranst, offenbar bedingt durch die hier sich anschliessenden, diffusen, feinen Adhäsionen, die übrigens auch hinter dem Uterus bis nach rechts hinüber und in der Beckentiefe zum Ausdruck kommen. Die rechte Tube scharf im Bogen nach oben verlaufend, durchwegs permeabel. Die Aufnahme ist im Moment des Austropfens des Kontrastmittels aus dem Fimbrienende erfolgt. Der Befund ist nicht bioptisch verificiert. Palpatorisch ergeben sich rechts normale Verhältnisse, links im Bereich der früheren Abtragungsstelle eine wallnussgrosse unscharfe Resistenz, dem Adnexstumpf entsprechend.

Fig 16. *J. N. 257/1926. R. N. 3617. Chronische Adnexerkrankung beidseits.* Dreieckform des Uterus infolge Abfliessen des Kontrastmittels fehlt. Dieses findet sich bereits im hintern Scheidengewölbe. Die Portio, welche in die Kontrastflüssigkeit eintaucht, markiert hier eine sehr schöne Aussparung, median vom Cervixschatten durchzogen. Von beiden Tuben ist eigentlich nur das dem Fimbrienende entsprechende Endstück erhalten, rechts etwas mehr, als links, beide Fimbrienenden scheinen verschlossen. Die rechte Tube und das rechte Ovar sind unter sich mit dem Uterus und der Kleinbeckenserosa verbunden durch zahlreiche Adhäsionen. Ähnliche Verhältnisse bestehen auch links, namentlich gegen das Sigmoid hin.

Fig. 17. *J. N. 248/1926. R. N. 3589. Myomata uteri mit submucöcem Polyp und beidseitg. chron. Adnexerkrankung.* Das unregelmässige (Polyp) verkleinerte Cavum

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

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Fig. 5.

Fig. 6.

Fig 7.

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.

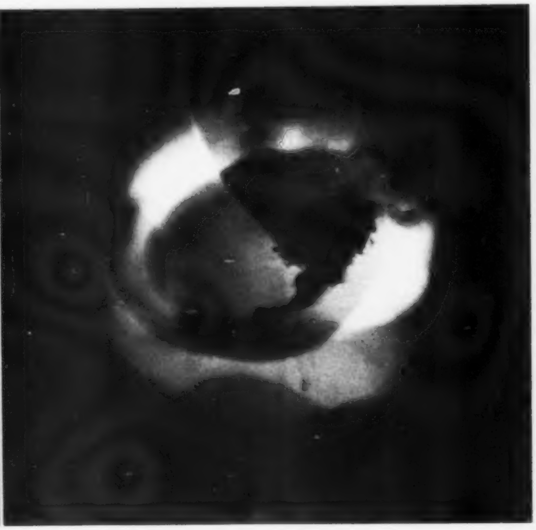

Fig. 12.

CTA R

Fig. 13.

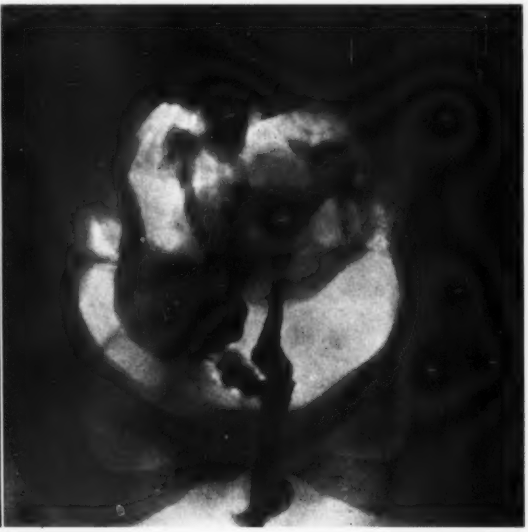

Fig. 14.

Fig. 15.

Fig. 16.

Fig. 17.

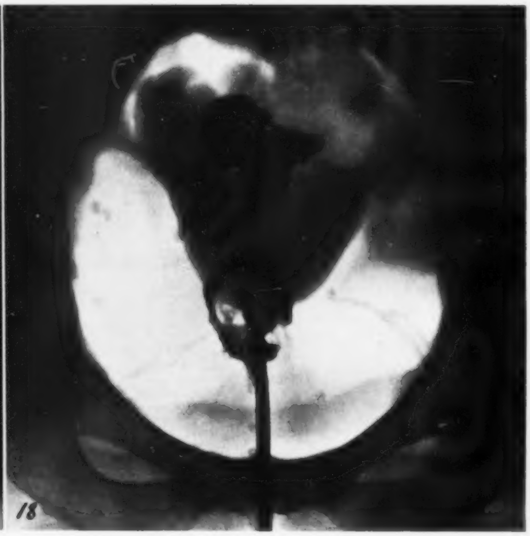

Fig. 18.

Fig. 18 a.

Fig. 19.

nach rechts extramedian gestellt. Von der rechten Tube nur das Fimbrienende erkennbar, die übrige Tubenpartie geht in einer dichten, ziemlich scharfen, dem rechten Horn direkt angelagerten Tumormasse unter, von der nach allen Seiten feine Adhäsionen ausstrahlen. Nach oben angelagert eine geblähte Darmschlinge. Die linke Tube gestreckt, zeigt nur in ihrer mittleren Partie auf kurze Strecke Kontrastschatten und verliert sich dann in einen linksseitigen ziemlich scharfwandigen Tumor, der auch das Ovar zu umschliessen scheint, und überall von Adhäsionen umgeben ist. Offenbar bewirken deren Nischen und Buchten auch hier wieder wie bei Fall 10 ein Verfangen des ausgeflossenen Kontrastmittels an einzelnen Stellen, z. B. rechts in einer Tasche über dem Fundus.

Bioptischer Befund.: Die rechte Tube in einen daumendicken Sack ausmündend der nach hinten übergeschlagen, das rechte Ovarium umschliesst und mit ihm eine Tumormasse bildet, dieser aufgelagert, eine geblähte Dünndarmschlinge. Die linke Tube ebenfalls sackartig erweitert, geht über in einen kleinapfelgrossen hämorrhagischen Tumor der sie selbst mit dem lateralen Pol des zugehörigen Ovars fest verbindet, sodass Tube und Ovar eine Tumormasse bilden. Überall feste Adhäsionen mit Sigma, Adnexen und Kleinbeckenserosa, rechts auch solche mit benachbarten Dünndarmschlingen.

Fig. 18. *J. N. 271/1926. R. N. 3635. Myomatöser Uterus mit beidseitigen Ovarialcysten.* Teils submucöse, teils noch intramural sitzende, (siehe beil. Zeichnung) Myomknoten bedingen die Unregelmässigkeit des Uteruscavums; besonders deutlich ist die Ausbuchtung im Bereich des rechten Horns. Die Tuben sind nicht erkennbar. Beiderseits vom Uterus und ihm dicht angelagert, unscharfe, die gesamten Adnexe in sich schliessende, und mit der ganzen Umgebung durch Adhäsionen verbundene Tumormassen.

Bioptische Kontrolle: Der Uterus faustgross knollig, mit verschiedenen intramuralen und einer Reihe kleinern, submucös gelegenen ins Cavum vordringenden Tumorknoten. Das rechte Ovar in eine Schokoladen-, das linke, in eine Corpusluteumcyste umgewandelt. Beide mitsamt den Tuben, dem Uterus und der ganzen Nachbarschaft durch Adhäsionen innig verwachsen.

Fig. 19. *J. N. 39/1926. R. N. 3221. Doppeltkindskopfgrosse, schlaffe, rechtsseitg. um 90° stieltorquierte Ovarialcyste.* Der Tumor ist scharf begrenzt und liegt der rechten Darmbeinschaufel auf. An seinem untern Pol in der Medianlinie das mangelhaft gefüllte unscharfe Cavumdreieck. Die rechte Tube fehlt, die linke Tube in ihrem ganzen Verlauf scharf gezeichnet, permeabel, mit Kontrastmittelausfluss an ihrem Fimbrienende.

FROM THE ROENTGENOLOGICAL DEPARTMENT AND THE ELECTROCARDIOGRAPHIC LABORATORY OF THE SERAFIMERLASARETTET, STOCKHOLM

A STUDY OF THE ACTIVITY OF THE HUMAN HEART, SIMULTANEOUSLY RECORDED BY X-RAYS AND ELECTROCARDIOGRAM

by

Nils G. Stenström and *Nils Westermark*

I. Description of the Technique and a Preliminary Report of Observations Made on the Normal Heart Contraction[1]

The first attempt to record the movement of the X-ray shadow of the heart-limit on a photographic plate moving behind a slit is published by the Polander SABAT (1). Principally the same technique independently of him was developed by GOETT and ROSENTHAL (1912) (2) and by GOETT (1913) (3). Simultaneously with X-ray curves, »Roentgenkymogramme», this author also recorded arterial pulse curves, but from what appears in his paper he did not use these for controlling the relationship between the contractions of separate points of the heart. A first attempt to analyse the X-ray curves with the aid of the electrocardiogram was made by BECKER (1914) (4). Later the American author CRANE (1916) (5) studied the movement curves — termed by him »Roentgencardiograms» — in various cases of heart disease and last year there appeared a paper by the English author KNOX (1925) (6), especially dealing with the X-ray technique, and another by the Americans COHN and STEWART (1924) (7), who have used the Roentgen-method for controlling the action of Digitalis on the heart.

The inductive disturbances in the string-galvanometer circuit, caused by the currents of the X-ray machinery, however, have been a severe obstacle for the simultaneous recording of the electrocardiogram and the X-ray curve. Because of this we are lacking in knowledge as to the meaning of the curves obtained with the X-ray technique referred to.

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[1] Communicated at the XII:th International physiological congress at Stockholm, August 1926.

According to our experience the wires from the electrodes to the galvanometer can without greater difficulty be made induction-free, but in the part of the circuit, made up by the electrodes and the body of the patient, the pulsating X-ray current always evokes an induction current. The force of this inductive disturbance varies considerably. It is not the same in different subjects, but, as the unprotected part of the galvanometer circuit acts as a solenoid or an induction coil, the greatest variations are found by changes in the position of the subject in relation to the X-ray machinery. A small movement may thus cause a most conspicuous change. When working with a powerful X-ray equipment, it is impossible in most cases because of the induction to get useful electrocardiograms and sometimes the outlines of the stringgalvanometer curve are completely abolished.

We doubt that these inductive disturbances in practical work can always be eliminated by the arrangement of metallic screens around the patient as attempted by Becker (l. c.). When this author has recorded useful electrocardiograms (in his paper there seems to be no real reproductions) it may be caused by favorable coincidence of special circumstances i. e. an individually low induction and a favorable position of the patient.

As we planned an investigation of the movements of different parts of the heart during certain pathological conditions the simultaneous electrocardiogram was necessary. In order to get suitable electrocardiograms in every position of the subject the Becker-method would not do. We therefore advanced another way, and tried to eliminate the disturbing induction by inducing another induction current in the galvanometer circuit in the opposite direction but with the same period and of about the same strength. Following this principle we have succeeded in getting useful electrocardiograms during the X-ray exposure.

II. Description of the Technique

Our technique, worked out empirically, has been as follows:

The X-ray laboratory and the electrocardiograph are situated in separate buildings connected with a cable and with telephones supported by the two operators. The patient, connected with the electrodes in the usual way, is placed between the X-ray tube and the apparatus for the falling plate. Around one section of the wires to the galvanometer the wire of a circuit is wound through an inductor in which a suitable number of turns can be engaged and which can be moved various distances from the X-ray machinery (fig. 1).

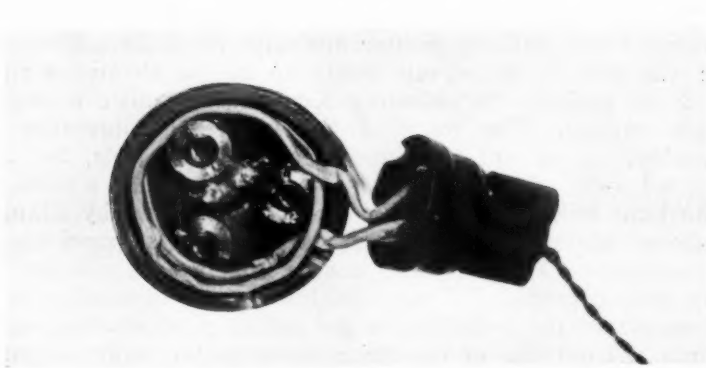


Fig. 1 B.

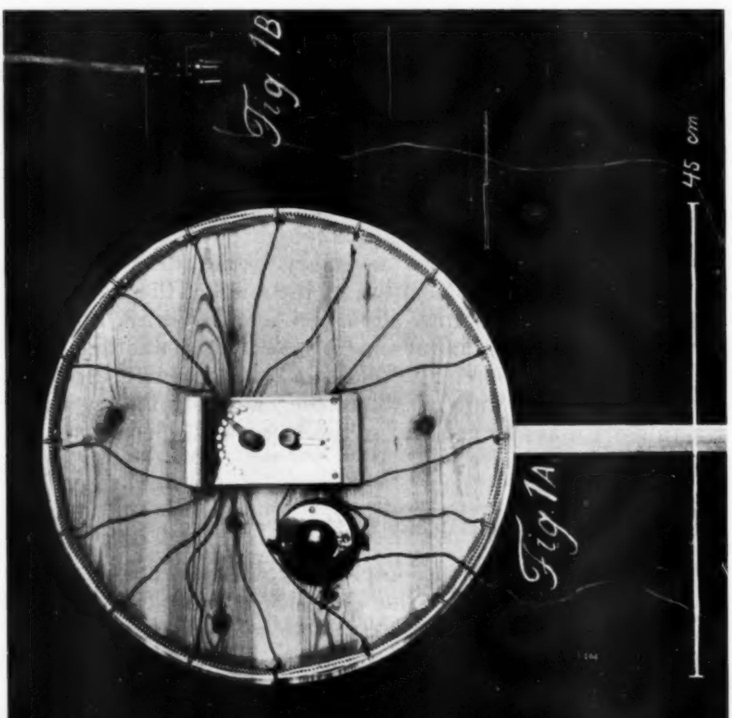
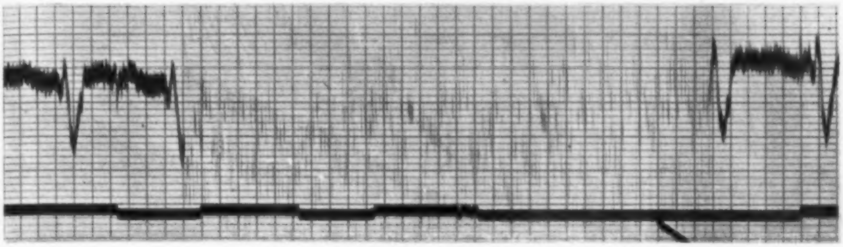
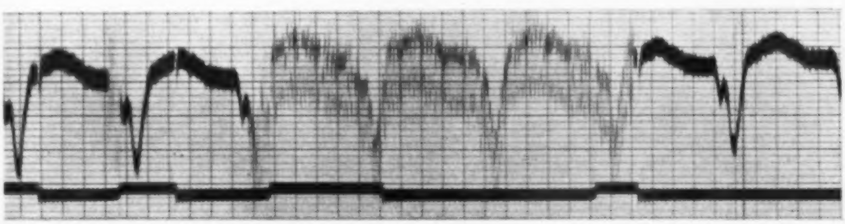


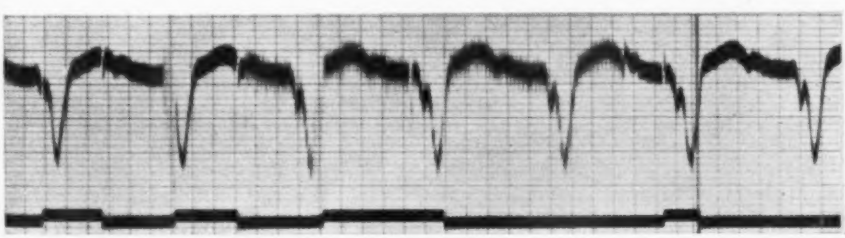
Fig. 1 A.



No compensation



Partial compensation



Compensation

Fig. 2. Inductive influence of the X-ray current on the string galvanometer circuit.

With the X-ray current switched on, the galvanometer circuit is exposed to a double inductive influence with the same period, from the patient and from the compensatory induction coil.

There are made repeated X-ray exposures (of about $^1/_2$ sec.) the one operator observing the galvanometer and the other varying the number of turns and the position of the compensatory induction coil until an optimum result is obtained.

In this way we have not succeeded in completely eliminating the induction, but in every case, especially since connecting a variable condensor with the inductory, it could be diminished and tuned so as to enable useful electrocardiograms to be obtained (fig. 2).

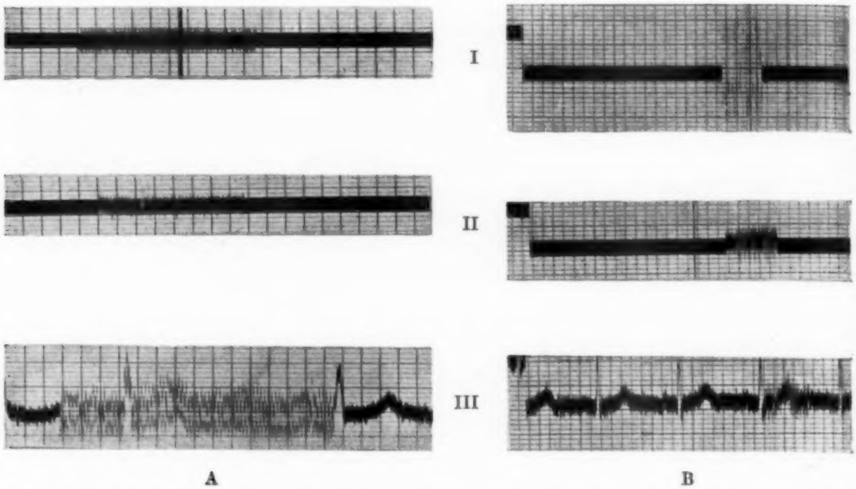
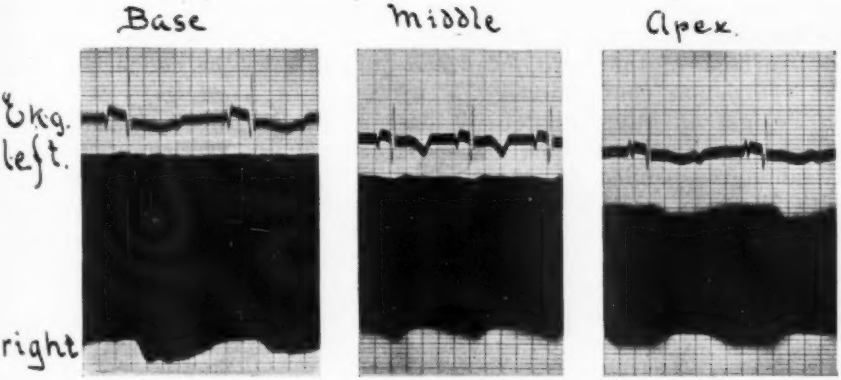


Fig. 3. The inductive influence in the area between the electrodes. A. Small resistance-box (2 000 ohm) shuts the circuit. B. Turn of wire arranged in series with this resistance. I. No compensation. II. Compensation. III. The resistance resp. resistance and wire exchanged for a patient.

That the work of the X-ray machinery is recorded in the electrocardiogram, makes it impossible to determine its timing with greater accuracy than of one period of the X-ray current (in our case 0.01 sec.) but as the X-ray curve is photographed through a relatively broad slit it hardly can be used to a more delicate timing. On the other hand the disturbance has this advantage that, as the falling rates of the plates for the X-ray curve and for the electrocardiogram are constant throughout the exposure, the time marker of the stringgalvanometer equipment may also be used for timing the X-ray curve.

In illustration of the force of the inductive influence in the space in front of the X-ray tube the experiments as shown in fig. 3 were arranged. In the left hand series of curves the inductive influences within a patient are compared with the influence on a small resistance box of the common type and in the right hand series the induction is shown to be about the same in the patient as in the box together with a single turn (50 cm. diameter) of copperwire arranged in the frontal plane of the patient.

The X-ray curves as well as the electrocardiograms are recorded on falling plates, the fall being controlled by glycerine pumps. The exposure, usually about 2 sec., is made at a time after the start of



I II III

Fig. 4. Movements of the shadow of a suspended rabbit's heart.

the plates when they have reached a constant rate. The opening of the slit in the X-ray »camera» was about 1 mm. at a rate of the plate of about 2 cm./sec. We have used Coolidge machinery of about 70 kilovolt and 40 milliampère. In order to get sufficiently good X-ray curves we have used a diaphragm with a very small opening (usually of 5 cm. diameter) in front of the tube and then placed the tube with the central ray just behind the point studied. The distance between the tube and the plate was then about 75 cm.

III. Observations of the Features of the X-ray Movement Curve in the Normally Contracting Human Heart

We began our work with the aim of investigating certain problems associated with pathological hearts but very soon found it necessary first to study the normal contractions. A preliminary report of our results on this point will be given below.

Previous authors have published rather uniform types of curves of the heart movement, most probably because they have all photographed nearly the same spots of the border of the heart. Judging from their papers there seem to exist rather constant and characteristic curves, one from the right and one from the left border, presumed to be caused by the contraction of the right auricle and the left ventricle respectively.

If, however, different points of the cardiac border are examined and the curves timed with the aid of the electrocardiogram one will

find the outlines of the curves varying from point to point and, furthermore, that the most conspicuous movement on every point of the surface of the heart, even the auricle, must be connected with the ventricular contraction.

To get an interpretation of these results, at the first sight confusing, we have examined the movements of an excised heart from a rabbit, suspended in the usual way in the aorta and nourished with Thyrode solution. The heart was arranged in front of the slit of the stringgalvanometer camera, its action currents led off by means of unpolarisable electrodes at the base and the apex. The electrograms and the movements of different points of the outlines of the heart shadow were thus recorded on the same plate. Fig. 4 obtained from this experiment, illustrates three types of curve produced by different mechanisms: In curve I, from the base of the heart, the left border (left ventricle) moves very slightly, but at each ventricular contraction the right border (right auricle at the limit of the ventricle) is pushed to the right. In curve II from the middle of the heart (the ventricles limiting the shadow) there are seen real systolic contractions, the right side contracting a little previous to the left. Curve III shows how the conic apex region at each contraction is drawn upwards thus simulating a real contraction of the pair of points contracting simultaneously.

By Roentgenological study of the heart beating in its normal position within the body one will find, that the outlines of the curves are determined, not only by actual contraction, but also by pushing and traction of other parts of the organ.

In a patient suffering from anaemia but without signs of heart disease curves were obtained from 23 points of the surface of the heart, none of them exactly like one another (fig. 5 and 6). In fig. 5 the movements of two points of the orthodiagraphic border, one above the other, were recorded simultaneously on the same plate. In fig. 6 the right and left border in a horisontal plane a little above the diaphragm were examined simultaneously, the schematic drawing representing three directions of the Roentgenrays through the body. The curves are copies from the Roentgenfilm and should be read from left to right. The times indicated above the notches of the curves refer to the interval from the rise of the R-summit and, when within brackets to the beginning of the P-summit in the first lead of the patients electrocardiogram. There are found two minima for these times, the one on the lower part of the right orthodiagraphic border (0.04 sec.) and the other in the neighbourhood of the vortex of the left ventricle (0.03—0.06 sec.).

In case of the remaining portion of the right border its lower

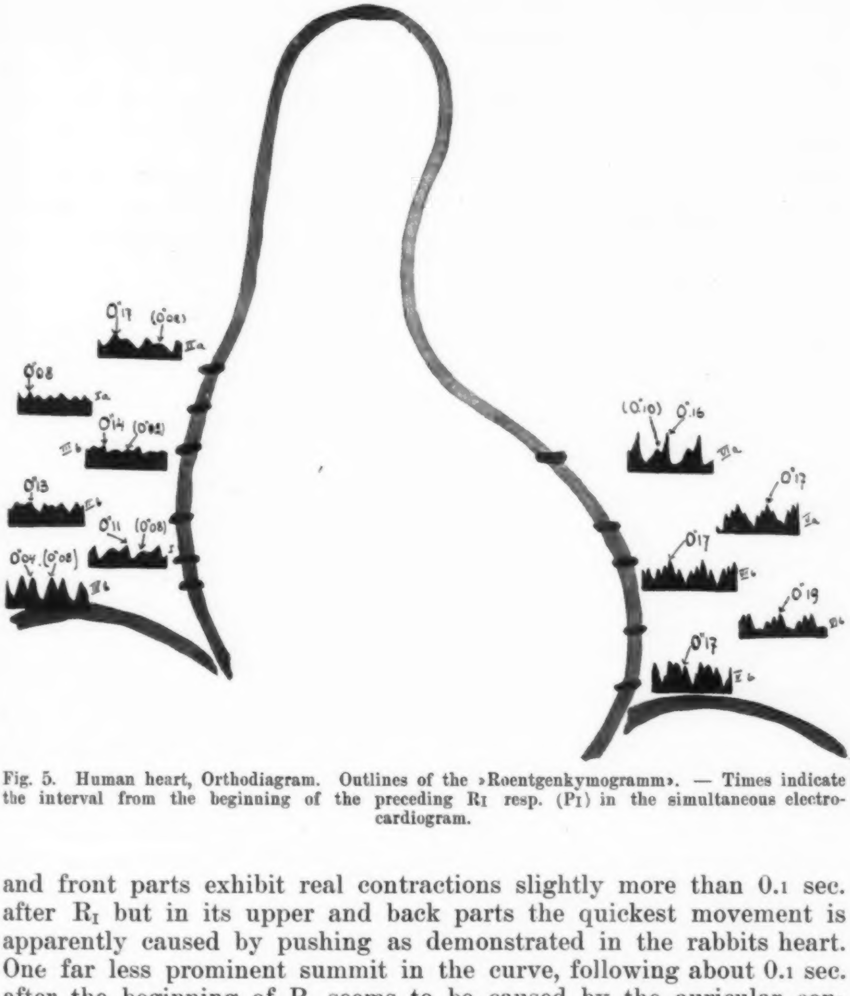


Fig. 5. Human heart, Orthodiagram. Outlines of the »Roentgenkymogramm». — Times indicate the interval from the beginning of the preceding R_I resp. (P_I) in the simultaneous electrocardiogram.

and front parts exhibit real contractions slightly more than 0.1 sec. after R_I but in its upper and back parts the quickest movement is apparently caused by pushing as demonstrated in the rabbits heart. One far less prominent summit in the curve, following about 0.1 sec. after the beginning of P, seems to be caused by the auricular contraction, being nearly synchronous with a summit in the curve from the left auricular region.

The curves from the left border are far more complex, consisting of series of notches, the most conspicuous of them presumably caused by the contraction at the point examined, appearing 0.11 sec. up to 0.28 sec. after the rise of R_I, the longer times referring to the back part. The smaller summits are most likely caused by pushing and

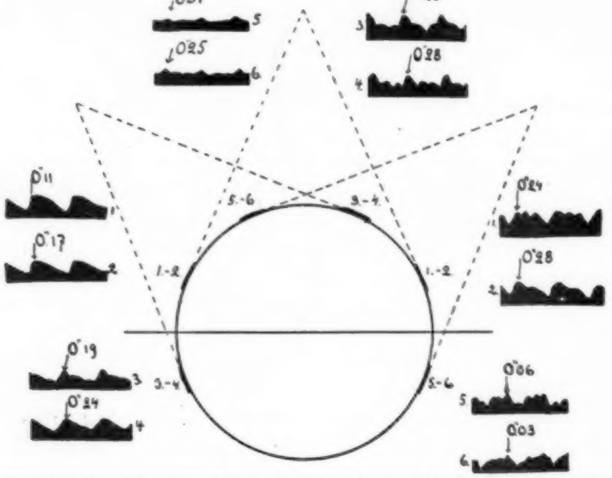


Fig. 6. The »Roentgenkymogramms» from points in the same horizontal plane around the heart. — Times give the intervals from the preceding R_I.

traction of the border line, when other parts of the heart are contracting. The most prominent excursions of the curves are obtained at the base and at the apex, where the direction of the movement is oblique to that of the slit which in the case of the curve from the apex of the excised rabbit's heart we know as traction.

The pairs of curves in fig. 6 are obtained at an interval of only some few seconds for the exchange of plates. Although the patient has kept his position as well as he could, there are remarkable changes in the outlines of the curves, indicating that he has moved, as was evident by the changes produced in the inductive forces in the galvanometer circuit. The changes in his position, not observed by himself or the operator, must have been very small and consequently the shape of the X-ray curve as well as the time of contraction may vary greatly in points close to each other. On the other hand, by repeated examinations of the patient we could get curves from the respective points very closely similar to those here published.

The results so far obtained from our investigations may be stated as follows:

The movement curves from different points of the heart vary considerably. Each point has its own characteristic curve, which can be recognized on repeated examinations. The interval between the electrocardiogram and the chief summit of the X-ray curve is

for a certain point constant but changes from point to point. Two minima for this interval are found, one on right and the other on the left ventricle in the apex-region.[1] The curve from the upper and back parts of the right border is most probably caused by the ventricle pushing the auricle to the right. The influence on the curve from the contraction of the right auricle is mostly perceptible but very little prominent. The left ventricular curve is the most complex one being made up of series of summits, all but one probably caused by indirect pushing and traction by the contraction of remote parts of the heart.

SUMMARY

The inductive disturbance caused by the X-ray machinery in the string-galvanometer circuit has been compensated by inducing in this an opposite induction current of the same period and strength. Following this principle the authors have succeeded in getting useful electrocardiograms during the X-ray exposure.

The movements of different points of the outlines of the heart have been photographed through a slit on a falling plate, generally two points at the same time, and then the curves have been compared with the electrocardiograms obtained simultaneously.

The authors give a preliminary report of the results with their technique.

The curves are probably caused by contraction of the border and also pushing and traction from other parts of the heart. The curves from the upper and back part of the right border are most probably caused by the ventricle pushing the auricle to the right.

Different points of the border of the heart show different curves. Each point has its own characteristic curve.

The interval between the electrocardiogram and the chief summit of the X-ray curve is for a certain point constant but it changes from point to point. Two minima for this interval are found one on the right and the other on the left ventricle in the apex region.

ZUSAMMENFASSUNG

Die durch den Röntgenapparat hervorgerufene Störung im Saitengalvanometer-Stromkreis wurde durch Einführung eines entgegengesetzten Induktionsstromes von gleicher Periode und gleicher Stärke kompensiert Bei Befolgung dieses Prinzips gelang es den Verfassern verwendbare Elektrokardiogramme während der Röntgenexposition zu erhalten.

Die Bewegungen verschiedener Punkte am Herzumfang wurden durch einen Schlitz auf eine fallende Platte photographiert; gewöhnlich wurden zwei Punkte zu gleicher Zeit vorgenommen und dann die Kurven mit den gleich zeitig erhaltenen Elektrokardiogrammen verglichen.

[1] We may point out the analogy between these results of our investigation and the times of electrical activity on the surface of the dog's heart found by LEWIS and ROTHSCHILD (8).

Die Verfasser geben einen vorläufigen Bericht über ihre mit dieser Technik erhaltenen Resultate.

Die Kurven sind wahrscheinlich durch Kontraktion des Herzrandes und auch durch Druck- und Zugwirkung von anderen Teilen des Herzens verursacht. Die Kurven vom oberen und hinteren Teil des rechten Randes werden wahrscheinlich durch den Ventrikel, der den Vorhof nach rechts schiebt, verursacht.

Verschiedene Punkte des Herzrandes haben sehr verschiedene Kurven, und die Kurve jeden Punktes hat ihre eigene charakteristische Form.

Das Intervall zwischen dem Elektrokardiogramm und der Hauptspitze der Röntgen-Kurve ist für einen gewissen Punkt konstant, es wechselt aber von Punkt zu Punkt. Zwei Minima dieses Intervalls finden sich — eines für den rechten und eines für den linken Ventrikel — an der Apexregion.

RÉSUMÉ

La disturbation inductive provoquée par l'appareil de Röntgen dans le circuit du galvanomètre à corde fut compensée en introduisant un courant induit contraire de période et d'intensité égales. En suivant ce principe, les auteurs ont réussi à obtenir au cours de l'exposition aux rayons de Röntgen des électrocardiogrammes propres à être employés.

Les mouvements de points différents du contour du cœur out été photographiés à travers une fente sur une plaque tombante, généralement deux points à la fois, sur quoi les courbes ont été comparées aux électrocardiogrammes simultanément obtenus.

Les auteurs donnent un rapport préliminaire des résultats obtenus à l'aide de leur technique.

Les courbes sont probablement dues à la contraction du bord du cœur, mais aussi à la pression et à la traction provenant d'autres parties du cœur. Les courbes obtenus aux parties supérieure et postérieure du bord droit sont avec la plus grande probabilité dues à la ventricule poussant à droite l'oreillette.

L'intervalle entre l'électrocardiogramme et la pointe dominante de la courbe Röntgen est pour un certain point constant, mais change de point en point. Deux minima de cet intervalle se trouvent — l'un au ventricule droit, l'autre au ventricule gauche — dans la région de l'apex.

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FROM THE LABORATORY OF THE FINSEN MEDICAL LIGHT INSTITUTE, COPENHAGEN.
CHIEF: CARL SONNE, M. D.

INVESTIGATIONS OF THE ACTION OF LIGHT UPON OXYGEN CONSUMPTION

by

Carl Sonne

It has for many years been an open question whether light exerts any influence upon the respiratory exchange. MOLESCHOOT[1] (1855) experimenting on frogs showed that these produced more carbon dioxide in the light than in darkness; however, as he paid no attention to whether the muscular activity of the animals was increased in the light, which it probably was, these experiments cannot be considered conclusive. Neither in a number of more recent experiments by various authors were standard conditions in this respect ensured. In the experiments in which this source of error has been reliably excluded, and where care has been taken to keep the animals as far as possible under uniform conditions of temperature in the light and darkness, no appreciable difference in the respiratory exchange under the two conditions could be detected. This obtains for the experiments made by JAC. LOEB[2] in 1888, and by EWALD[3] in 1892. JAC. LOEB worked on various insects in the pupal stage which must be said to afford perfect standard conditions, as the animals do neither take food nor perform muscular contractions. He determined the metabolic exchange of the pupae by measuring their loss of weight in definite periods; it is true that the values he found showed considerable variation, but there was no indication of any regular relation between the findings for light and darkness. EWALD in a series of very careful experiments on curarized frogs could not detect any difference of effect either. Referring to these experiments KROGH[4] points out that with regard to the fundamental problem they are not convincing, for, as the ani-

[1] Wien. med. W. Nr. 43, 1855.
[2] Pfl. Arkiv. 42, 1888.
[3] Journ. of Physiol. 13, 1902.
[4] The Respiratory Exchange of Animal and Man. London 1916.

mals selected for experimentation were opaque the light could not to any essential degree have penetrated the skin and, thus, not have acted directly on the cells in which the metabolic processes take place, i. e. muscle-cells and secretory cells.

In my opinion, however, the demonstration in very recent years of the marked effect of light energy, — more especially of the ultraviolet frequencies upon the mineral metabolism of animals, gives a new aspect to the problem.

For instance, some investigations by SCHULTZER[1] undertaken at the Laboratory of the Finsen Light Institute, showed that even a transitory radiation with ultraviolet rays applied to the skin of young rats, which had not been shaved, that is to say, a skin surface which is all but impervious to such rays —, may under such conditions produce a considerable effect on intestinal resorption. If such a superficial action upon the skin can give rise to radical changes in the mineral metabolism, a similar action might equally well be imagined to have some influence on the respiratory exchange, perhaps even in the form of some reaction closely interrelated with changes produced on the mineral metabolism. In this connection it must be pointed out that the light energy utilised in LOEB's and EWALD's experiments could have very little effect as compared with modern phototherapeutic radiation. The animals were boxed up in glass-vessels and, as far as can be understood, »illumination» means nothing but exposure to diffuse day-light through the glass-walls of the vessel. Thus, ultraviolet rays were quite out of the question and even the exposure to the luminous rays has been minimal. Therefore, as regards the effect of a strong light-energy — such as is applied for therapeutic purposes —, upon the respiratory exchange, LOEB's and EWALD's investigations are without importance. HASSELBALCH, in 1905, published a series of studies of the influence of the universal carbon-arc light-bath upon respiration in man, including also the respiratory exchange; he could not detect any reaction on the part of the latter. However, the examinations were not undertaken until several hours had elapsed after the light-bath was discontinued; I shall refer to this later.

Quite recently HARRIS[2] has published some experiments on the effect of light, among other things, on the carbon-dioxide production on rats. He found an increased quantity of carbon-dioxide liberated under ultraviolet radiation, that is to say, with rays which from a mercury-quartz lamp were passed through a filter of blue uviol glass, while, strange enough, the unfiltered light from the lamp did not

[1] Comptes rendus d. s. d. l. Société de Biologie, T. XCIII, p. 1005.
[2] Proc. of the royal soc., Serie B. Vol. 98, B. 688, p. 171, 1925.

produce any effect. These experiments of HARRIS can however scarcely be considered convincing. His remark to the effect that he preferred to make carbon-dioxide determinations instead of oxygen determinations, as the latter would yield less accurate results, seems to indicate that his experiments were not very successful, since it is a well-known fact that the quantity of carbon dioxide liberated during respiration is a far more variable factor than the quantity of oxygen absorbed. HARRIS claims that the animal shall sit motionless during the experiment, otherwise he rejests the test. That the rat under radiation nevertheless may be under muscular activity — for instance by performing increased movements of the respiratory muscles with ensuing increased ventilation of carbon dioxide, he seems to ignore. On the whole, he works with experimental conditions which have long ago been abandoned by both EWALD and JAC. LOEB. These two authors maintain that it is not possible even in hibernating animals or in frogs whose spinal cord has been cut through, to avoid increased muscular movements under radiation; and, if this is the case, one cannot attach much importance to HARRIS' experiments.

The writer's investigations were performed partly in 1918 and partly in 1925—26. The experiments of 1918 must be considered chiefly as introductory, serving to develop the technique eventually adopted; as will appear from the following pages, the first series of experiments yielded however results which were corroborated by the second series. That I did not bring the experiments to a conclusion in 1918 was due to the fact that, at a certain time, it proved impossible, notwithstanding great efforts, to procure experimental material, the reason why I set to work on some other photo-biological experiments in which I was engaged for several years. It was not until recent years' investigations had shown how great an influence the ultraviolet light rays may have upon the intermediary mineral metabolism, that my interest was again roused for this question and I felt called upon to take up and carry on my former experiments in order to try to get a better understanding of the action of the chemical light rays also upon the respiratory exchange.

Selection of Animals for Experimentation

As has been said, when employing opaque animals in such radiation experiments, we cannot presume that a direct action upon the cells that are particularly active in the metabolic processes, is obtained. If a reaction was to be expected in such animals it must be an indirect one, effected for instance through the nervous or the

vascular systems. Therefore, I considered it of great importance that the animal should be under as natural conditions as possible; so I did not employ narcotisation or curarisation. Like JAC. LOEB, I therefore chose to work on insects in the pupal stage as the only ones suitable for the purpose, and, since the chrysalids of the mealworm (Tenebrio) were the easiest of access, I chose these. Their size — ranging from 1 to 1.5 cm in length — permits of an accurate determination of the oxygen absorption within a reasonable period; they do not take food; and, under normal conditions, their muscles are perfectly inactive. The duration of their pupal life is from two or more weeks, depending largely on the temperature. According to investigations by KROGH (among others) the respiratory exchange is somewhat increased at the beginning and towards the end of the pupal period, while, in the interval, it remains very steady. I have worked on chrysalids whose metabolism was perfectly constant from hour to hour. By vigorous external irritation, for instance, pressure with a pair of pincers, the mealworm pupa may perform an isolated straightening movement of the abdomen, which however immediately darts back again; with certain types of radiation I have witnessed similar movements, as will be mentioned later in connection with the experiments; such a movement will of course exert some influence on metabolism. If such movements do not occur, it is presumably warrantable to suppose that no muscular activity has taken place, and, consequently, no disturbance of the metabolic processes on this account. The slightly curved position of the chrysalid, the concavity of the ventral side, is not due to any muscular tension; the chrysalid retains the same curvature a long time after being killed. That increased respiratory exchange should occasionally occur owing to augmented muscular tone without its being manifest in observable movements I do not think there is any reason for assuming, nor do I think this has been alleged by previous observers. This question will however be further discussed in connection with the experiments.

The chrysalids are not enclosed in any sort of web or cocoon, so they are readily accessible to photo-therapy. The rudimentary wings lie folded together anteriorly on the fore-body. As will appear in the following description I have successfully utilised these rudiments of wings partly for suspension of the animal in the respiratory chamber and partly for placing a thermo-needle for measuring the temperature of the animal.

The Method used for Determining the Consumption of Oxygen by the Chrysalids of Meal-Worms

The oxygen intake has been determined by means of KROGH's micro-respiration apparatus, which was especially devised for the determination of the respiratory exchange on small animals and which has been elaborately described in several works.[1] It consists of a manometer of capillary bore supplied with two branches, in which two fairly similar glass vessels are suspended, the one serving as respiration chamber, the other as »compensating» vessel. When the two vessels are immersed in the same water-bath, which is kept well-stirred, while the manometer is kept outside, changes of the gas volume of the animal chamber will be recorded on the manometer, the result read being proportional to the change effected, in the case of issue to the volume of oxygen consumed by the chrysalid suspended in the vessel; the carbon-dioxide liberated simultaneously is absorbed by a layer of 1 cc. of 2 per cent NaOH covering the bottom of the vessel. When the capacities of the vessel and the conducting tubes are known quantities, as are also the lumen of the manometric tube and the specific gravity of the fluid in the manometer (kerosene), we have the means, on the basis of the value recorded by the manometer, of obtaining an exact determination of the change in gas volume. For this purpose KROGH has devised a formula. As, in my experiments, there was not a question of determining the absolute respiratory exchange, but only the percentage changes in the same animal, I need not enter further into this formula. The consumption of oxygen being proportional to the value recorded by the manometer, the results are in the present work given in manometric millimeters throughout.

The Source of Light Applied in the Experiments and the Arrangement for Radiation

For radiation of the chrysalids a KROMAYER lamp was applied throughout; this is, as is well-known, a mercury quartz-lamp supplied with a water-cooling apparatus, in the way that cold water is continually kept circulating through the water-chamber of the lamp by means of afferent and efferent rubber tubes, connected with the source of water supply. As the respiration-chamber of the spiro-

[1] For instance in Biochemische Zeitschrift 62, 1914, and The Respiratory Exchange of Animal and Man. London 1916.

meter into which the chrysalid is enclosed, is placed in a water-bath, the lighted lamp must also be immersed in the water-bath; the special construction of the KROMAYER lamp permits of this immersion, if only the conductors be coated with rubber tubing. The lamp is suspended in a frame which readily permits of varying its distance from the object to be illuminated. The respiration-chamber (see Fig. 1 p. 429) being a glass vessel of a capacity of about 35 cc. air, has a circular aperture of about 2 cm. in diameter supplied with a projecting collar. A disc of quartz is fixed air-tight on to this collar by means of piscin (a tough, though easily liquefying sealing-wax); the chrysalid is suspended behind this quartz pane in the manner described below. When an experiment is in progress, care is taken to keep the quartz pane of the lamp and that of the respiration-chamber at the same level and parallel with each other. Respiration-chamber and compensating vessel are by means of a band fastened to a metal plate, which is again fastened to the frame of the manometer.

In order to enable the observer to study the effect of various frequencies of light, a glass cuvette of a thickness of 1 cm. and supplied with a tight fitting lid may be placed in front of the quartz-pane of the lamp. Various filtering fluids may be placed in this cuvette, as will be mentioned.

The Influence of Temperature upon the Respiratory Exchange of the Chrysalids of Meal-Worms

Before proceeding to a detailed account of the radiation experiments, the influence of temperature upon the respiratory exchange must be briefly mentioned. When the luminous source applied is diffuse daylight only, it causes little difficulty to keep the chrysalid under the same temperature whether illuminated or not. The calorific energy emitted by this illumination is so slight that it will scarcely cause an appreciable rise in the body-temperature of the chrysalid. It is of course different when there is a question of radiation from a strong source of light which may emit considerable calorific energy. Heating of the chrysalid will however in itself give rise to considerable increase of the metabolic processes, and, as it is of course not this thermal effect which it is desired to determine, but the specific reaction excited by the light alone, if such takes place, without regard to its calorific energy, I devised special procedures in my experiments in order to eliminate the thermal error. Before describing the experimental devices for this purpose, some few determinations of the influence of temperature on the

pupal metabolism will be given, so that the reader may be orientated in regard to the order of quantities concerned. The suspension of the chrysalid in the chamber and the further arrangement is the same as will be described later.

When the oxygen consumption by the chrysalid has been determined by some time's observation at one temperature, hot water is added to the water-bath and another determination is undertaken, when the metabolic processes can be considered to be at rest.

	Bath-temp.	Manometric record		
$^{12}/_{6}$ 1918.	18.2° C.	12.0 mm in	62 minutes	— 0.194 in 1 min.
	19.6° C.	24.3 » »	102 »	— 0.238 » 1 »
$^{1}/_{10}$ 1925.	18.0° C.	5.2 » »	60 »	
	19.3° C.	6.4 » »	60 »	

that is the same increase of 16 per cent per one degree's rise of temperature in two different chrysalids, the determinations undertaken at an interval of seven years.

The first Radiation Experiments of 1918

In these experiments as well as in those performed later in 1918 it was my object to compare the effects of blue and yellow light frequencies upon the respiratory exchange of the chrysalids; for this purpose, a glass cuvette, containing either a methylene-blue solution or a potassium-bichromate solution, was placed in front of the KROMAYER lamp in the water-bath, the object under observation being radiated alternately with these two lights, and the value recorded by the manometer being noted for the two types of radiation. The main point to me was of course to take care that the chrysalids were kept under uniform temperature while exposed to the two kinds of light.

The first fairly successful results in this respect were obtained by the following experimental device:

A thermometer is placed into the respiration chamber so that its mercury container, being approximately the same size as a mealworm pupa, is inside the chamber behind the quartz pane. The mercury container was blackened by means of a thin layer of smoke-black mixed with paraffin. When the chrysalid suspended in a fine thread, is placed parallel to this thermometer, these two objects are under equal conditions of radiation. In the tests, I regulated the source of light so that the same rises in temperature were registered by the thermometer whether the blue or the yellow lights were applied. As the results obtained by these means proved to correspond exactly to those arrived at later by means of a modified and more

reliable technique, I propose to quote them here, giving at first a more elaborate description of one of the tests in order to show the progress of same.

Experiment undertaken $^{23}/_{4}$ 1918, the chrysalid being placed in the chamber the previous day.

At 9.30 a. m. the apparatus was placed in a water-bath of 20.5° which was kept well stirred.

At 10.30 a. m. the manometer was closed and the lamp, which had been previously switched on and supplied with a methylene-blue filter,[1] was placed closely in front of the quartz-pane of the spirometer. During radiation the temperature changes registered by the thermometer were read off about every second minute and noted. The results were:

a rise from 20.5° C. to 22.4° C. during the first 10 minutes,

an oscillation between 22.4° to 22.1° C. during the last 50 minutes.

At 11.30 a. m. the lamp was switched off; the temperature of the water-bath was at this juncture 19.7, at which point it is kept by continuous mixing until

12 noon, when the manometer read 27.8 mm. The manometer was opened and the temperature of the water-bath was again brought up to 20.5°, at which point it was kept until

12.45 p. m., when the manometer was closed and the lighted lamp again placed in front of the quartz-pane, being this time supplied with a filter of potassium-bichromate.[2] The distance between lamp and object is varied somewhat during this test so as to keep the rises of temperature as far as possible within the same limits as with the test with the blue light, i. e.

20.5° to 22.5° during the first 10 minutes.

22.5° to 22.3° during the last 50 »

At 1.35 p. m. the lamp was switched off, the water temperature being 19.7°, at which it was kept until

2.15 p. m. when the manometer read 24.5 mm. The manometer is opened, the bath temperature being brought up to 20.5° and

at 3 p. m., a methylene-blue filter is again interposed between the lighted lamp and the object to be radiated. The temperature during radiation oscillated from 20.5° to 22.3° C. during the first 10 minutes and from 22.3 to 22.9 and 22.1° C. during the last 50 min.

At 4.00 p. m. the lamp was switched off, the water-bath temperature being 19.7°.

At 4.30 p. m. the manometer read 27.6 mm.

The experiment was discontinued.

Thus, with approximately the same rises of temperature registered by the blackened thermometer the following manometric values of the respiratory exchange of the chrysalid were obtained:

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[1] In these first experiments the luminous intensity of this filter was not determined in percentage, but only spectroscopically, as the layer of one cm applied was just sufficient to eliminate the yellow line.

[2] Saturated solution.

1) Radiation with blue light for 60 minutes + 30 minutes without radiation 27.8 mm.
2) Radiation with yellow light for 60 minutes + 30 minutes without radiation 24.5 mm.
3) Radiation with blue light for 60 minutes + 30 minutes without radiation 27.6 mm.

that is exactly the same absorption of oxygen in the two tests with blue frequencies; and an absorption about 13 % less in the yellow light, although the temperature was slightly higher, if anything. In a few preceding tests with other pupæ I arrived at corresponding results, i. e.

19/4 1918	Yellow light	first 10 min. 22.5 to 25.0° C.	+ 30 min. without radiation at 19.4°. Manometric record 16.3 mm.
		last 50 min. 25.0 to 24.8° C.	
	Blue light	first 10 min. 22.0 to 23.8° C.	+ 30 min. without radiation at 19.4°. Manometric record 17.6 mm.
		last 50 min. 23.8 to 24.0° C.	

Notwithstanding the fact that the temperature was about one degree higher in the yellow-light test than in the blue-light test, the oxygen absorption was higher in the latter.

20/4 1918	Blue light	first 10 min. 20.0 to 21.8° C.	+ 30 min. without radiation at 18.5°. Manometric record 34.0 mm.
		last 50 min. 21.8 to 21.0° C.	
	Yellow light	first 10 min. 20.2 to 21.8° C.	+ 20 min. without radiation at 18.5°. Manometric record 31.2 mm.
		last 50 min. 21.8 to 21.4° C.	

Thus, in all three experiments the respiratory exchange was highest in the blue light.

However, I soon realised that these experiments were open to objections. I have included them in the present work partly to illustrate the progress of my experimentation, and partly because the tests, in spite of the objections which can be made, but which are evidently not fatal, show results which correspond very well with those of my more recent experiments, which I believe to be fully reliable. Against the former experiments it may be objected that the rise of temperature registered by the blackened thermometer placed beside the chrysalid, cannot be equal to the temperature rise in the yellowish pupa, which will reflect a portion of the light rays, and even a different quantity according as the yellow or the blue light is concerned. In order to get an impression of the rôle played by these factors I illuminated simultaneously two thermometers, placed side by side, which were exactly alike, except that the one had its

mercury container coated with black-coloured paraffin, the other with yellow-coloured paraffin (by means of potassium bicarbonate) of a shade resembling that of a meal-worm pupa. This testing showed that, when the column of the black thermometer under radiation rose two degrees (almost corresponding to the rise witnessed in the experiments), the yellow thermometer showed a rise of 1.8 degrees in the blue light and of 1.4 degrees in the yellow light. As the rise in the oxygen intake was calculated to be 16 per cent for one thermal degree, this means that the respiratory exchange of the pupa under the yellow radiation should be raised by $0.4 \times 16 = 6.4$ %. Even though the results of the experiments of $^{23}/_{4}$ and $^{20}/_{4}$ be corrected to this effect, the final results will still show higher values for oxygen consumption in the blue-light tests, just as in the experiment of $^{19}/_{4}$, in which the pupa has undoubtedly been heated to a higher degree during the radiation with the yellow light.

For some time I deliberated, as a more reliable method, to apply in the respiration chamber a thermometer of approximately the same colour as the pupa, but before I had carried through a similar series of experiments as the above, I adopted another technique, on which, since that time, my experimentation has in the main been based.

Radiation Experiments from 1918, in which the Temperature Measurements are Undertaken by Means of Thermo-Needles

In these experiments I have endeavoured to measure the temperature of the pupa directly during radiation. As previously mentioned the rudimentary wings of the insect lie folded together anteriorly on the slightly concavely curved ventral side of the animal. About 4 millimetre of a slightly bent, thin metal wire can easily be introduced beneath these wings so as to lie totally covered. If this conductor consist of bits of copper and constantan wire, the ends of which are welded together, they will constitute a thermo-element, by means of which the temperature beneath the wings may be measured. Thus, if the ventral side of the insect is exposed to the light, we obtain the temperature of the radiated part without the thermo-element being directly exposed to the rays. As the temperature will of course be decreasing from the radiated part inwards, I placed a thermo-element also on the other side of the animal (dorsally), in order to be able to determine the average temperature of the entire pupa. This element consists of a thin silver plate, about 1 mm square in size, welded to a copper and to a

constantan wire, and placed tightly on the back of the insect. In fact, the suspension of the pupa in the respiration chamber is performed entirely by means of these thermo-elements; it is supported by the thermo-needle under the wings on the ventral side being abruptly bent round to the dorsal side so as not to be directly exposed to the light-rays at any part; it is fixed and kept in position by support from the thermo-element placed on its back. The wires of the thermo-element, being of a suitable rigidity, are arranged so that the pupa is suspended at the level of the quartz-pane of the chamber, the wire emerging through a side-pipe fitted air-tight into the cork of the vessel by means of piscin (cf. Fig. 1). On to this pipe is slided a piece of rubber-tubing, through which the wires are led after leaving the vessel so as to keep them out of the moisture, when the apparatus is immersed in the water-bath. Further the wires are distributed as shown in Figure 1 and 2.

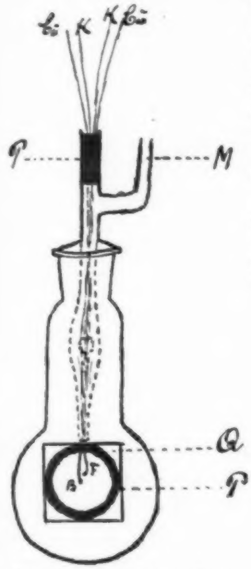


Fig. 1. Respiration chamber (cf. description under Fig. 2).

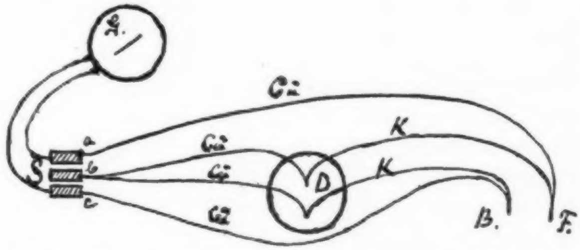


Fig. 2. Diagram representing current distribution. F and B: thermo-needles for front and back of animal. Q: quartz-pane. P: piscin sealing. M: tube leading to manometer. Cu: copper-wire. K: constantan wire. S: current distributer. G: reflecting galvanometer. D: Dewar vessel.

The two copper-wires emerging from the respiration chamber are connected each with one terminal of a current distributer, while the constantan wires are connected with a Dewar vessel (thermo-bottle), where they are welded to two copper-wires placed each separately in a glass tube closed at the bottom end, the opposite ends of the copper-wires being connected with the middle leaf of the current distributer. The thermo-elements in the Dewar vessel (thermo-bottle) containing water are interposed in order to furnish a standard temperature to go by instead of the somewhat variable room-temperature. By connecting a, b, and c, with each other in different ways the following temperatures may be measured: When the circuit is

completed between b and c and broken between a and b, the temperature of the ventral side of the pupa is obtained, that is to say, the value recorded by the galvanometer corresponds to the difference between the temperature of the ventral side and that of the DEWAR vessel (D); when the circuit is completed between a and b and broken between b and c, the temperature of the dorsal side of the pupa is obtained in same manner, and, finally, when b is cut off both from a and c, the result registered by the galvanometer shows the difference between the front and back temperatures. Calculation of the galvanometric value into thermometric degrees, with the given arrangement of galvanometer, galvanometer lamp and graded scale, is easily made by once for all placing the two thermo-elements »front» and »back», in water of known, but varied temperatures. In my experimental arrangement of 1918 one centimetre's deflection on the galvanometric scale corresponded to 0.1 degree, that is a highly sensitive thermometer. In my work of 1925—26, 1 cm corresponded to 0.36 degree, which gave sufficient accuracy, as it was possible to measure an additional 0.05° which was very convenient to work with.

The same lamp and the same filters for blue and yellow radiation were employed as in previously mentioned tests; likewise the test arrangement was so that, by regulating the distance between the source of light and the test-object, care could be taken that the rises of temperature occurring in the pupæ during the two kinds of radiation were fairly uniform. When the object had been exposed to one kind of radiation for 60 minutes, the temperature of the water-bath was kept constant by continuous stirring for 30 minutes to follow, after which time the manometric record was read. The manometer is opened and, when some time has again elapsed, the same procedure is carried on with the other kind of radiation. Occasionally, radiation through the filter which had first been applied was repeated in the end of the experiment in order to examine whether this would give results identical to the initial test. During the whole process the temperatures of the front and back of the chrysalid have been followed by frequently shifting the contacts of the current distributer, the temperature of one side being followed most of the time, though, occasionally, for one or two minutes, the difference between the temperatures of the two sides is noted. The temperature is regulated, as previously mentioned, by varying the distance between the lamp and the pupa. Thus, the lamp will, as a rule, be moved a little nearer to the object when blue light is applied, since the yellow light is richer in calorific energy than the blue; however, as a rule, the difference in distance does not exceed $^1/_4$ to $^1/_2$ cm. The cool water stream through the lamp

was regulated so as to keep the temperature of the water-bath constant.

The lamp has been adjusted to full-power current throughout. The chrysalid together with a 1 cc layer of 2 % NaOH has been placed in the chamber, and this immersed in the water-bath for a lengthened period, frequently from the day previous to the commencement of the experiment. The water is mixed by means of a propeller driven by a motor.

All the experiments with yellow and blue light performed in 1918 in accordance with the test-arrangement described, are stated below, and, besides, an isolated experiment in which a copper-ammonia-sulphate filter was employed instead of methylene-blue. Besides these experiments a few others were undertaken in 1918, using other filters, but as they were not completed that year, I shall forbear describing them.

I shall commence by describing three experiments in which the pupa was radiated first with blue and then with yellow light on the same day. The first two tests were made with the same pupa in the same suspension, as it was not removed from the chamber in the interval between the tests. Here, as in previous tests, the temperatures given represent only the rise occurring in the pupa during the first 10 minutes and the greatest oscillations read during the following 50 minutes.

Table 1

No.	Date	Bath temp.	Temperature of pupa during blue radiation		Reading of manometer after 30 min.	Further standing without radiation for	Temperature of pupa during yellow radiation		Reading of manometer after 30 min.	Percentage rise of metabolism from yellow to blue radiation
			Back	Front			Back	Front		
1	23/5	19.5°	first 10 min. 19.5°–20.7° last 50 » 20.7°–20.3°	+0.4°	20.1 mm	80 min.	first 10 min. 19.5°–20.8° last 50 » 20.8°–20.3°	+0.4°	16.8 mm	+ 19.6 %
2	24/5	19.0°	first 10 » 19.0°–20.0° last 50 » 20.0°–19.9°	+0.3°	18.2 mm	70 »	first 10 » 19.0°–20.0° last 50 » 20.0°–19.9°	+0.3°	16.2 mm	+ 12.4 %
3	25/5	18.9°	first 10 » 18.9°–20.1° last 50 » 20.1°–20.1°	+0.3°	30.2 mm	60 »	first 10 » 18.9°–20.1° last 50 » 20.1°–20.0°	+0.3°	26.2 mm	+ 15.4 %

Just as in the previous tests the table shows that the respiratory exchange is considerably higher in the blue light than in the yellow. In all these experiments the blue-light-test preceded the yellow-light-test; in the following experiment No. 4 the yellow light was applied first, then the blue, and afterwards again yellow. Moreover, in this experiment, the respiratory exchange of the pupa was determined three times when not under radiation, i. e. prior to first radiation,

and in the intervals between the first and second, and the second and third radiation.

This experiment was carried out in the following manner:

Date: Exp. No. 4.

27/4 1918: The spirometer containing the pupa has been left in the water-bath since 26/5. Temperature of water-bath 17.9° C.

1) Manometric record read after 45 minutes' standing without radiation: 6.6 mm = 13.6 mm in 90 minutes.
2) Yellow light for 60 min. — back temp. first 10 min. 17.9 to 18.7° C.; last 50 » 18.7 » 18.8° C.; front temp. + 0.3 — manometric record: 15.8 mm.
3) Standing without radiation for 30 minutes.
4) After standing without radiation for 75 minutes: Manometric record: 11.6 mm = 13.8 mm in 90 minutes.
5) Blue light for 60 min. — back temp. first 10 min. 17.9 to 18.7° C.; last 50 » 18.7 » 18.7° C.; front temp. + 0.3 — manometric record: 17.7 mm.
6) Standing without radiation for 30 minutes.
7) After standing without radiation for 25 minutes: Manometric record 3.8 = 13.7 mm for 90 minutes.
8) Yellow light for 60 min. — back temp. first 10 min. 17.9 to 18.8° C.; last 50 » 18.8 » 18.8° C.; front temp. + 0.5 — manometric record: 15.8 mm.
9) No radiation for 30 minutes.

It appears from this test that, while the respiratory exchange was the same in the two tests with yellow light (15.8 mm), it rose to higher values in the interposed blue-light-test (17.7 mm = 12 %). The readings taken prior to the experiment and at the intervals between radiation were perfectly identical. Thus, neither the blue nor the yellow light had exerted any after-effect on metabolism, at any rate, not after a period of 30 minutes had elapsed. When I have accounted for Experiments 5 and 6, I shall return to Exp. 4.

Exp. No. 5 is a counterpart to Exp. No. 4, in that a yellow radiation was interposed between two blue radiations.

8/6 1918. Exp. No. 5.

Bath-temperature 17.8° C.

Blue light for 60 min. — back temp. first 10 min. 17.8 to 18.7° C.; last 50 » 18.7 » 19.1° C.; front temp. + 0.25 — + 30 min. without radiation: manometric record: 22.3 mm.

Yellow light for 60 min. — back temp. first 10 min. 17.8 to 18.7° C.; last 50 » 18.7 » 19.0° C.; front temp. + 0.25 — + 30 min. without radiation: manometric record: 20.8 mm.

Blue light for 60 min. — back temp. first 10 min. 17.8 to 18.6° C.; last 50 » 18.6 » 18.9° C.; front temp. + 0.25 — + 30 min. without radiation: manometric record: 22.2 mm.

Thus, again, the respiratory exchange was lowest in the yellow light, the values being somewhat higher (7.2 %) though quite uniform, in the two tests with the blue light.

In Exp. No. 6 an ammoniacal solution of copper-sulphate was substituted for methylene-blue in the filter. This gave a very dark blue, almost blackish hue; consequently, only a small amount of light has passed the filter, which, as will appear below, is manifested by a minimal rise of temperature in the pupa during radiation. Presumably on the same account the specific reaction on metabolism is also quite negligible with this blue radiation; still, as the result points in the same direction as in the previous tests, it is of some interest as compared with these, although, as an isolated experiment it is scarcely of any great value.

Date: *Test No. 6.*

11/6 1918: Water-bath temp. 18.9° C. (copper-sulphate-blue filter).

1) Blue light for 60 min.	back temp.	first 10 min. 18.9 to 19.3° C. last 50 » 19.3 » 19.3° C.	+ 30 min. without radiation: manometric record: 20.6 mm.
	front temp. + 0.1		
2) Yellow light for 60 min.	back temp.	first 10 min. 18.9 to 19.3° C. last 50 » 19.3 » 19.4° C.	+ 30 min. without radiation: manometric record: 19.8 mm.
	front temp. + 0.1		
3) Blue light for 60 min.	back temp.	first 10 min. 18.9 to 19.1° C. last 50 » 19.1 » 19.2° C.	+ 30 min. without radiation: manometric record: 20.3 mm.
	front temp. + 0.1		

That is values which, in spite of the less intense radiation, point in the same direction as in all the previous tests.

Utilising the results of Exp. No. 4 I have attempted a computation of the absolute action on the respiratory exchange exerted by the two different kinds of light. In the experiments recorded in the following pages, undertaken more recently, these factors will be further elucidated. If, in Exp. No. 4, a rise of 16 per cent in the oxygen consumption is calculated for each added thermal degree, we may, consequently, with an average rise of temperature during radiation of 0.9° C., calculate a rise of about 14.5 per cent of the normal respiratory exchange for 60 minutes. The latter being $13.7 \times \frac{60}{90} = 9.1$ mm, the rise in metabolism caused by the temperature will, consequently, equal $9.1 \times \frac{14.5}{100} = 1.3$ mm.

For determination of the absolute oxygen consumption during radiation we must further correct an error which has not previously been mentioned. It was observed that the action of the rays on

the respiration chamber alone, without pupa, may cause a slight fall in the manometric value, that is to say, what I have called a contraction of the air-volume, occurs presumably owing to formation of nitrous oxide or the like, perhaps also to formation of ozone. Later, I have subjected this contraction to a closer investigation, as will be mentioned below; in this connection I shall only state that, in 1918, I found this error to be exactly the same for blue and yellow radiation, when the source of light, as in the experiments at issue, was placed very close to the quartz-pane of the respiration-chamber. In both cases a contraction of 0.9 mm was registered in the course of 60 minutes' radiation of the chamber.

On applying these findings to Exp. No. 4, we must, besides the 1.3 mm, add another 0.9 mm to the 13.7 mm, which represent the normal metabolism, in order to obtain the value expected under the supposition that the light energy has no specific action on metabolism. The resulting equation is thus $13.7 + 1.3 + 0.9 = 15.9$. As this value is, as it were, identical to the value found in the two radiations with yellow light, i. e. 15.8 in both cases, it follows that the yellow frequencies in this test cannot have had any action whatever on the oxygen consumption. As far as the blue light is concerned, the matter is different, since there is a difference of 1.8 mm; the manometric record being 17.7 mm instead of 15.9, although the rise of temperature and contraction were exactly the same. As the experimental period did not exceed 60 minutes, during which time the normal value for oxygen absorption at the same temperature is $9.1 \text{ mm} + 1.3 \text{ mm} = 10.4 \text{ mm}$, a rise of from 10.4 to 12.2 mm produced exclusively by the blue colour of the light is seen to occur in one hour, i. e. an increase of 17.3 per cent.

Résumé of the Experiments Performed in 1918

With a vigorous radiation by means of a Kromayer lamp, supplied with a methylene-blue filter and a potassium-bichromate filter, respectively, both in the forms of solutions enclosed in a glass cuvette, the blue frequencies of the spectrum produce a higher rise in the oxygen consumption by the chrysalid than the yellow frequencies, the temperature conditions being equal. This is shown in a series of uniform experiments. Judging from an isolated test the rise in the respiratory exchange evoked during radiation with yellow light is exclusively due to the increase of temperature in the pupa incident to the radiation; the yellow frequencies produced thus no effect in themselves. In contradistinction to this, radiation with the blue light had a specific accelerating influence on metabolism. In

one of the tests the increase of oxygen intake during one hour's radiation was found to amount to 17.3 per cent.

Experiments in 1925—1926

The experimental technique in these experiments was, to a certain extent, like that previously described. Spirometer, respiration-chamber, suspension of the pupa by means of thermo-needles and radiation with the KROMAYER lamp immersed in the water-bath, all corresponded exactly to previous tests. In one respect, however, the more recent series of experiments differed essentially from the earlier, namely, in the way in which the temperature of the pupa was regulated during radiation. While in the first series, the temperature of the pupa was allowed to rise during radiation, care being only taken to secure the same rise in the two different kinds of radiation, in the later series, the temperature of the pupa (or rather the »front» temperature) has been kept constant during radiation and uniform with the temperature of the water-bath prior to, and subsequent to, radiation. This arrangement permits of a direct reading of the specific reaction excited by the light as compared with the normal metabolism without radiation, irrespective of the calorific effect of the light. This uniformity of temperature was obtained by regulating the emission of heat by the pupa during radiation; this was done by reducing the temperature of the water-bath in which the respiration-chamber containing the pupa is immersed just so much that the temperature of the pupa is kept at a constant level. In practice the water-cooling apparatus of the lamp is utilised to this end, the water current, whose velocity can be regulated very minutely by means of a screw pet-cock, and which after having circulated in the lamp, is again conducted to a discharge sink, acts as a cooler or heater of the water-bath, which is constantly mixed by means of a vigorous motor propeller also during radiation. As will appear later from the temperature variations in the tests, this regulation can be adjusted very minutely; only, at the commencement of the test, the radiation should not be too intense, the lamp therefore being kept as far from the pupa as possible, and on the weekest current available; after some practice I succeeded however soon in augmenting the light energy to the desired amount in the course of 4 to 5 minutes, at most, without causing any appreciable changes in the temperature of the pupa. When radiation is discontinued — in these experiments 45 minutes at a stretch was the maximum experimental period — the lamp should be removed from

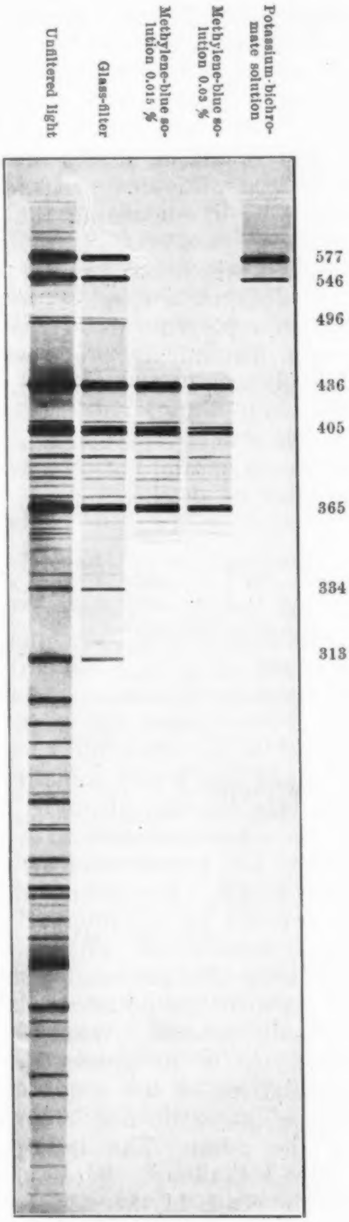
the water-bath as quickly as possible, while, simultaneously, a suitable amount of hot water is added so that, in the course of about one minute — before the temperature of the pupa can have changed to any appreciable extent —, the initial temperature of the water-bath is re-established. When the bath is kept well-stirred, the fall in its temperature with the light energy applied in these tests, need not exceed 1 to 2 degrees.

Reading of the manometric record after radiation can of course not take place until all the parts of the spirometer in the water-bath have again assumed a perfectly uniform temperature, which required from 15 to 30 minutes. As, by this mode of procedure, it is rendered possible directly to determine the influence of the light upon the respiratory exchange without paying regard in one's calculation to the simultaneous effect on the temperature, it was not necessary in these experiments, as in the earlier series, exclusively to undertake comparative investigations of different radiations of the same pupa. Instead, the tests were carried out simply as follows: Firstly, the normal oxygen consumption by the pupa is determined at the given temperature, as this is not considered as being established unless identical manometric values have been obtained in several successive periods of equal length; as a rule, I noted the readings of 3 periods of 15 minutes, in the least. When the normal respiratory exchange is thus a known factor, the manometer having been read off a radiation period is commenced immediately and continued for 45 minutes; when this is completed, and the bath-temperature at once again brought up to the initial temperature, the manometer is read off at intervals of 5 minutes. Gradually, as the differences of temperature of the various parts of the spirometer are eliminated, the values recorded by the manometer become more and more uniform within the same period, being as a rule identical from the 15th to the 30th minute after the radiation has been stopped, as previously pointed out. Having made quite sure that the respiratory exchange persists at a constant level, for instance during 3 times 15 minutes, one has a means of determining not only a possible reaction of the respiratory exchange *subsequent to radiation*, but also *during* radiation. The latter reaction may be determined in so far as we take for granted that the respiratory exchange, immediately after radiation has been discontinued, is the same as the respiratory exchange determined 30 minutes later, an assumption we are forced to make, and which cannot, at any rate, involve any error of practical importance. Hence, we can easily infer the manometric value due immediately after cessation of radiation, if the differences of temperature in the spirometer could have been eliminated at

that juncture. The difference between this supposed manometric record and the record read at the commencement of radiation, thus yields a value for determining the respiratory exchange during radiation. For further details concerning these experiments the reader is referred to the Tables subjoined. The reading of the manometer has been performed by means of a loupe and an aiming-line. By these means it has been possible to accurately read off until 0.1 mm.

The Light Energy Employed and the Determination of its Intensity

The source of light was, as in previous tests, a KROMAYER-lamp immersed in the water-bath. The intensity of the light has been varied partly by means of the resistance inserted in the conductor of the lamp and partly by varying the distance between the lamp and the object. In the series of tests here concerned I worked with four types of light, viz. 1) the unfiltered light from the lamp, 2) the light passed through a glass-filter, i. e. the glass cuvette containing water alone, 3) the light passed through a methylene-blue filter: the glass cuvette containing methylene-blue in a 0.03 or 0.015 per cent solution, 4) the light passed through a potassium-bichromate-filter: the cuvette containing a saturated solution of the salt. The spectra of the various light-intensities are given below.



These spectra show that the glass filter cuts off all the ultraviolet rays beyond the 313 $\mu\mu$, this line and line 334 however only being passed to a slight extent. The two methylene-blue

filters permit the passage of the frequencies between wave-lengths 436 $\mu\mu$ and 365 $\mu\mu$, i. e. the visible light-rays within the blue and violet region of the spectrum and the ultraviolet line 365; the potassium-bichromate filter only allows passage of the yellow and blue rays which are not passed by the methylene-blue filter. The intensity of radiation, in the absence of filter and with the various filters, has been measured in irradiated calories per time unit. I find, that this way of measuring the light and comparing the results with the spectra, yields the most accurate information of the light energy applied which our present knowledge permits of obtaining. On the following table (page 440) the different calorific energies that have been employed, are given. The calories were determined by the same method as previously described in another work (Acta Med. Scand. vol. LIV, fasc. IV), that is, by radiation of a blackened silver-plate which constitûtes one terminal of a thermo-element with which a determination has previously been undertaken by means of a HEFFNER-lamp of how many calories correspond to a certain deflection of a reflecting-galvanometer.

Contraction of the Air-Volume with the Radiation Applied

As briefly mentioned when describing the earlier experiments, radiation through the quartz-pane of the respiration chamber, and perhaps also to some extent radiation of the other parts of the chamber, may exert some influence on the air-volume in the chamber. For, when the empty chamber, without pupa, had been subjected to radiation for 45 minutes (the experimental period applied), a slight fall would sometimes be observable in the manometer, presumably brought about by some molecular contraction. In this connection the formation of nitrous oxide or of ozone would seem most likely, but I shall forbear giving an opinion as to the actual causative factor. Formation of ozone presumably only occurs when air is exposed to radiation of ultraviolet light; the contraction was also most pronounced with this quality of light, although it could be distinctly demonstrated also with radiation through glass alone; and, even with the potassium-bichromate filter, when the light was sufficiently intense. What is of practical importance in the present work is, 1) to correct the error caused by this contraction in the calculations of the respiratory exchange, and, 2) to ensure that new-formed gases do not in themselves influence the respiratory exchange of the pupa. The last point will be more elaborately dealt with later, I shall only here surmise that the investigations showed that the presence of these gases had no appreciable influence on the re-

spiratory exchange. The results of the quantitative determinations of the contraction in the various types of radiation are specified in the table below (p. 440). These determinations were made as follows: Firstly, by observation for a lengthened period of the closed manometer with the spirometer immersed in the well-stirred water-bath, it is ensured that the manometric pressure remains perfectly steady; secondly, radiation is commenced with the given source of light of the given intensity for the stipulated period; thirdly, the lamp is removed, the water-bath brought up to the initial temperature; and, finally, the manometer is watched, as a rule for about one hour, to make quite certain that the pressure is again absolutely constant.

I believe it warrantable to maintain that the contraction observed is not due to any defective technique, as for instance, leaks or the like, caused by the special construction of the respiration chamber. On the one hand, the contraction appears with a certain regularity according to the nature and intensity of the light, and, on the other hand, on several occasions, I exposed the spirometer to violent differences of temperature immediately after radiation in order to make perfectly sure of its tightness. Below, such a »tightness-test» is described:

The spirometer, with respiration-chamber, not containing pupa, but a layer of 1 cc of a 2 % NaOH solution, is placed in a water-bath of 20.3° C. When the fluid in the closed manometer has for a lengthened period stood fixedly at zero, the apparatus with the closed manometer is removed to another water-bath of 10.3°; 5 minutes later it is again moved to the first bath; in the course of 50 minutes the kerosene in the manometer again gradually travels back to zero; when it has been standing at this level for some time, the respiration-chamber is radiated for 45 minutes through methylene-blue filter (0.015 % solution) the lamp being placed close to the quartz-pane. When the lamp had been switched off and removed, the bath temperature showed 18.4°; this is immediately raised to 20.3°, and 30 minutes later, the manometer points definitely at ÷ 0.5 mm. That this contraction caused by radiation is real is further tested by again moving the spirometer, all the time without opening the manometer, to a water-bath of about 11.5° for 5 minutes and then back to the initial water-bath. After the exspiration of about 1 hour the manometer points again at − 0.5, at which level it remains.

If there had been the least »detachment» in the piscin sealing of the apparatus this would absolutely have become manifest when the instrument was exposed to the violent changes of temperature both before and after radiation. The manometer did however not register any change. Only radiation was able to cause the kerosene of the manometer to move, the reading keeping unaltered for a long period afterwards.

In the table below giving the values for the contraction at different radiations the amount of calories irradiated with given ad-

justment of the lamp is also noted. By amount of calories is meant the quantity of gram-calories irradiated to one square centimeter per minute. Under »lamp adjustment» the current consumption by the lamp is represented by the figures 1 to 3, i. e. »weak» and »strong»; and, besides, the distance between lamp and object is given in centimeters. In some of the experiments the peripheral portions of the circular quartz-disc constituting the pane of the respiration chamber has been darkened by a piece of tin-foil[1] fastened on the outside, leaving however an unscreened area in the middle somewhat exceeding the size of the pupa, through which radiation takes place. As the degree of contraction to some extent depends on the size of the pane, determinations had to be made both with the partially screened and with the unscreened disc, such as will appear in the table.

Table 2

Adjustment of lamp		Gram-calories	Contraction in millimeter, with a quartz-pane area	
Power	Distance	per cm^2 and minute	of 230 mm^2	of 110 mm^2
		Without filter		
1	10 cm	0.02	0	0
1	10 »	0.02	0	»
1	10 »	0.02	»	»
1	2 »	0.27	2.8	»
3	5 »	0.62	1.7	»
3	5 »	0.62	»	0.7
3	4 »	0.83	»	0.5
3	4 »	0.83	»	0.7
3	3 »	1.06	3.4	»
3	3 »	1.06	»	1.8
		Glass-filter (i. e. glass-cuvette containing water)		
1	1 cm	0.24	1.1	»
3	1 »	0.90	»	0.4
		Blue filter (0.08 %[1] and 0.015 %[2] Methylene-blue solution)		
1[1]	4 cm	0.02	0.2	»
1[1]	1 »	0.05	0.5	»
3[2]	1 »	0.35	1.4	»
3[2]	1 »	0.35	»	0.5
3[2]	1 »	0.35	»	0.5
		Yellow filter (saturated potassium bichromate solution)		
1	1 cm	0.08	0.4	»
3	1 »	0.41	1.1	»
3	1 »	0.41	»	0.2

The figures found in the table testify that the values for contraction are, as a rule, very small. In the spirometer used each

[1] Originally devised in order to cover the piscin and ensure that »contraction» could not result from radiation of same.

millimeter recorded by the manometer corresponds to a difference in air-volume of 2.81 cubic millimeter. So that, when the respiration-chamber contains 38 cc air, a contraction of 1 mm means a decrease in the air-volume of 0,0074 per cent. However, even so slight a diminution of volume may play some rôle in the final result of the respiratory exchange experiments, and a correction should therefore be made. It was found that the smaller the area through which radiation takes place, the less becomes the value for contraction. It is somewhat higher for the unfiltered light, containing plenty of ultraviolet rays but is also found in the radiation with filtered light. Moreover, it is usually found to increase with increasing calorific energy of the same type of light, however, only to a certain extent, the distance between lamp and object playing evidently also a rôle in itself; at any rate, it was found that, with a lamp-distance of 2 cm, the unfiltered light gave a contraction of 2.3 mm, with a calorific energy of 0.27, while a calorific energy of 0.62 gave only 1.7 mm, the distance in the latter case however being 5 cm, as the lamp was on »strong» current, while in the former test it was on »weak» current. Besides, the quality of the light is not quite the same with strong and weak current, as in these two cases. Possibly, it may also have some influence if the lamp in each test has not been adjusted exactly alike in proportion to the quartz-pane; when the lamp is close to the pane, it is perhaps not a negligible factor what part of the horse-shoe-formed burner of the lamp directly emits the light to the pane.

In by far the majority of the respiratory exchange experiments which are to be described in the following pages, all these minor inaccuracies in the determination of the contraction are however of little or no interest. In most of the experiments the radiation applied was comparatively so weak as to give room only for very small contractions of the air-volume, at any rate so small that even variations of 50 % or more of the correction value to be introduced, cannot compromise the final result. In the few experiments in which the result is more uncertain owing to a fairly high contraction error, this will be notified.

Determination of the Oxygen Consumption in Radiation Tests with the Unfiltered Light of the Kromayer-*Lamp*

As regards this type of radiation it must be admitted that in some of the tests the chrysalid was occasionally seen to perform some rapid movements of the abdomen, evidently due to the stimulus of the light. When such movements were observed, it has been

noted; as will appear later, it was by no means in all the tests that such movements took place. The abdominal movement during radiation consists in a rapid straightening movement of the posterior part of the body, darting back again immediately. When occurring at all, it was seen once only in a minute and scarcely more than 10 times at most in the course of an experimental period of 45 minutes. It is reasonable to assume that these movements play some rôle in the result of the oxygen consumption determined, as will be further discussed below.

Previous to a tabular representation of the experiments with this type of radiation I propose to give a more elaborate description of the first test in which correction of the error for contraction was introduced, in order to make known the experimental course and the method of calculation.

Experiment No. 5 (Table 3).

Immediately previous to this test the chrysalid had been exposed to radiation with blue light (No. 2, Table 4). Observed for 3 times 15 minutes prior to the blue radiation the standard metabolism of the chrysalid showed 1.3, 1.3, and 1.3 mm (i. e. 1.3 mm in each consecutive 15 minute period). Again, when the blue-radiation had been discontinued for 15 minutes, the manometer read 1.4, 1.3, and 1.3 mm in three successive 15 minute periods, that is to say, a standard metabolism of 1.3 mm per 15 minute period.

Subsequently, the chrysalid was exposed to the unfiltered light, the lamp being on »weak» current (1), and placed at first at a distance of 8 cm from the object; this distance is gradually diminished down to 2 cm in the course of 4 to 5 minutes. The initial water bath temperature was 19.2° C. The front temperature of the chrysalid showed some transitory oscillations of from 19.5 to 18.6°,[1] but remained on an average about 19.1°. The back temperature was 0.2° lower, viz. 18.9°. During radiation the bath-temperature fell a few degrees. As soon as the 45 minutes had elapsed, and the light had been turned off, the temperature of the water-bath was immediately brought up to 19.2°.

At the commencement of radiation the manometer showed — 13.2 mm.

Manometric record		Hence a variation per 15 minutes of
15 min. after discontinuance of radiation	— 22.6 mm	
		1.8 mm
30 » » » » »	— 24.4 mm	
		1.53 »
180 » » » » »	— 39.7 mm	
		1.5 »
195 » » » » »	— 41.2 mm	
		1.5 »
210 » » » » »	— 42.7 mm	

Hence follows

an oxygen consumption	prior	to radiation	of 1.3 mm	per 15 minutes
» » »	subsequent	» »	» 1.5 »	» 15 »

Increase of oxygen cons. subsequent to radiation = 0.2 mm, viz. 15.4 %.

[1] The oscillations in the other tests were, as a rule, not nearly as marked.

Table 3

Oxygen Consumption in Radiation-tests with Unfiltered Light

No.	Date	Calories irradiated per minute and per cm²	Bath temp.	Temperature of pupa during radiation			Oxygen intake per 15 min.		Radiation for 45 minutes			Increase in oxygen consumption		Abdominal movement during radiation	
				Front		Back	Prior to radiation	Subsequent to radiation	Manometric record calculated	Minus contraction	Respiratory exchange	During radiation	After radiation		
				Maximum reaction	Average temp.										
1	30/11	0.02	19.4	19.9—19.2	19.6	19.6	1.55	1.8	8.4	0	8.4	80.8 %	16.1 %	+	quartz-pane area of respiration chamber 230 mm²
2[1]	2/11	0.02	19.1	20.1—18.3	19.2	19.2	2.8	3.1	7.0[1]	0	7.0	25.0 %	10.7 %	0	
3	3/11	0.02	19.1	19.4—18.7	19.1	19.1	1.85	1.4	6.4	0	6.4	58.0 %	3.7 %	0	
4	9/11	0.02	19.1	19.3—18.8	19.1	19.1	1.9	1.9	7.5	0	7.5	31.6 %	0	0	
5	11/11	0.27	19.2	19.5—18.6	19.1	18.9	1.3	1.5	8.5	2.3	6.2	59.0 %	15.4 %	(+) (?)	
6	22/11	1.06	20.4	20.6—20.2	20.4	19.9	1.2	1.6	7.5	3.4	4.1	16.1 %	33.3 %	0	
7	24/11	1.06	20.1	20.2—20.0	20.1	19.5	1.9	2.1	9.8	3.4	6.4	12.3 %	10.5 %	(+)	
8	26/11	0.70	18.8	18.7—18.9	18.8	18.4	1.25	1.6	10.0	0.7	9.3	158.0 %	28.0 %	+	quartz-pane 110 mm
9	28/11	0.62	21.1	21.2—20.9	21.0	20.8	2.3	2.3	11.2	0.7	10.5	52.1 %	0	(+)	
10	6/11	0.62	18.5	18.6—18.4	18.5	18.2	2.7	3.1	10.0	0.7	9.3	14.8 %	14.8 %	(+)	
11[2]	10/11	0.03[2]	19.5	19.9—19.2	19.5	19.4	1.65	1.9	8.4	0.7[2]	7.7	63.9 %	15.2 %	(+)	

[1] Exposed for 30 minutes only.

[2] Another lamp contraction specially determined in this case.

The formula for the oxygen consumption during 45 minutes' radiation is therefore as follows:

$$42.3 - 210\frac{1.5}{15} - 13.2 - \text{contraction} = 8.5 \text{ mm} - 2.3 \text{ mm} - = 6.2 \text{ mm},$$

while the normal metabolism without radiation for 45 min. equals

3×1.3 mm $= 3.9$ »

Hence an increase of oxygen consumption during radiation of $= 2.3$ mm, or 59.0 per cent.

In this experiment the value for contraction is unusually high. A possible error in the estimation of contraction is therefore a factor of some importance. Still, although the value for contraction may in this case involve some inaccuracy, there can be no doubt that the oxygen consumption was considerably augmented during radiation.

The table shows, that even a very considerable increase in the respiratory exchange takes place in most cases during radiation, most frequently the increase ranges about 40 %; in a single case it amounts to 158 %. Besides, in the great majority of the cases there was a fairly marked increase also *subsequent to* radiation, 15 per cent on an average.

These experiments yield no information as to what agents are active in causing the variations in the percentage increase in metabolism in the various chrysalids; especially, there is no evidence that the strongest light excites the greatest reaction; it should be borne in mind, however, that even the »weakest» light employed in these tests is in reality a very vigorous radiation. In tests 1 and 8, a severally repeated abdominal movement on the part of the pupa during radiation has presumably contributed to the particularly high values in the result (81.8 % and 158 %, respectively); otherwise it appears that the increase may be just as pronounced in the tests in which movements had not been observed, as in those in which the chrysalid had shown weak signs of movement only [marked (+)]. It is mainly in tests 5, 6, and 7, that the value for contraction may be said to entail some uncertainty as to the calculation of the respiratory exchange during radiation. A contraction value higher than 3.4 mm was never observed by me, so, possibly, the values stated in these tests are too high; and, consequently, the increase in metabolism stated for Nos. 6 and 7 (16.1 % and 12.3 %, respectively) would be too low, if anything. As for the main principle of the question, whether radiation with the unfiltered light from the KROMAYER-lamp has any influence on the oxygen intake, this little uncertainty with regard to the correction for contraction is of no importance whatever. According to these experiments it must therefore be considered established that this type of radiation exerts a

considerable accelerating influence on the respiratory exchange under the given conditions.

As for the metabolism *subsequent to* radiation, an increase was found in 9 out of the 11 pupæ experimented upon. The respiratory exchange determined subsequent to radiation remained in all the cases absolutely constant as long as it was observed, in some cases for several hours, as seen for instance in Experiment 5, in the more elaborate description. Muscular movements in the pupa subsequent to radiation were never observed; error on account of contraction is of course out of the question in this connection.

As for the further behaviour of the chrysalids after radiation it may be stated that the day following the radiation they showed marked pigmentation on the exposed side, most marked between the rings of the abdomen and along the sides, where, in streaked areas, they might be almost jet-black; the pigmentation was far less pronounced in the upper part of the body. They kept alive, i. e. moved the abdomen when stimulated by pressure, for 2 to 3 days after radiation; afterwards they withered and died; as far as I know, none of the pupæ which had been subjected to this type of radiation, completed their development.

Determination of the Oxygen Consumption in Radiation Tests with a KROMAYER-*Lamp Supplied with a Glass Filter and with Blue and Yellow Colour-Filters*

In none of these tests was the pupa observed to perform any movements during radiation. The same pupa in the same suspension was in some cases used for two or more successive tests with different types of radiation, though of course not until its respiratory exchange had been established to be constant and at the same level as prior to radiation, so that it was warrantable to conclude that there was no reaction from the preceding radiation when the next test was commenced. Besides, the experiments of 1918 testified with all probability that such a procedure is permissible, in as far as two uniform »blue-radiations» gave identical findings in spite of a yellow radiation in the interval, or, vice versa, corresponding results in two yellow radiations with an intervening blue radiation. After exposure to unfiltered light which, as appeared from the previous tests, as a rule brought about an increase in metabolism which persisted for a long period, giving moreover rise to pigmentation, the chrysalid was never utilised in further experiments. I shall therefore also premise that pigmentation was never seen in the tests

with filtered light, subsequently to which the chrysalids seem to continue their normal development.

Table 4

Oxygen Consumption in Radiation-tests with Filtered Light

No.	Date	Calories irradiated per min. and per cm²	Bath temp.	Temperature of pupa during radiation			Oxygen intake per 15 min.		Radiation for 45 min.			Increase in oxygen consumption		Quartz-pane area of respiration chamber
				Front		Back	Prior to radiation	Subsequent to radiation	Manometric record calculated	Contraction	Respiratory exchange	During radiation	After radiation	
				Maximum reaction	Average temp.									
				Radiation through glass-cuvette alone										
1	5/11	0.01	18.9	19.2—18.6	18.9	18.9	1.6	1.6	5.7	0	5.7	18.8 %	0	230 mm²
2	10/11	ca. 0.15	19.1	19.4—18.9	19.1	19.1	1.3	1.3	5.2	0.5*	4.7	20 5 %	0	»
3	21/11	0.90	22.3	22.5—22.1	22.3	22.0	1.6	1.6	7.3	1.4	5.9	22.9 %	0	»
4	27/11	0.90	20.1	20.2—19.7	20.0	19.7	2.0	2.0	7.8	0.4	7.4	23.3 %	0	110 mm²
5	9/11	0.90	20.0	20.1—20.0	20.0	19.7	5.0	5.0	16.9	0.4	16.5	10.0 %	0	»
				Radiation through glass-cuvette containing methylene-blue (0.03 %[1] or 0.015 %[2])										
1[1]	7/11	0.01	19.4	19.5—19.4	19.4	19.4	1.75	1.75	5.95	0	5.95	13.4 %	0	230 mm²
2[1]	11/11	0.03	19.2	19.3—18.9	19.2	19.2	1.3	1.3	4.6	0.2	4.4	12.8 %	0	»
3[1]	20/11	0.20	20.4	20.8—20.1	20.4	20.3	2.15	2.25	7.3	0.8*	6.5	0.8 %	4.6 %	«
4[2]	27/11	0.35	20.1	20.1—20.1	20.1	20.0	1.9	2.0	7.0	0.5	6.5	14.0 %	5.3 %	110 mm²
5[2]	8/11	0.35	20.7	20.9—20.6	20.7	20.6	4.6	4.6	15.1	0.5	14.6	5.8 %	0	»
				Radiation through glass-cuvette containing potassium-bichromate (saturated solution)										
1	6/11	0.02	19.2	19.3—19.1	19.2	19.2	1.7	1.7	5.0	0	5.0	÷ 2.0 %	0	230 mm²
2	9/11	0.08	19.1	19.2—19.0	19.1	19.1	1.9	1.9	5.7	0.4	5.3	÷ 7.0 %	0	»
3	21/11	0.35	22.3	21.8—22.6	22.3	22.2	1.6	1.6	5.7	0.9*	4.8	0	0	»
4	8/12	0.41	20.7	20.8—20.6	20.7	20.6	4.6	4.6	14.1	0.2	13.9	0.7 %	0	110 mm²

* Contraction determined by interpolation.

The table shows that in none of the types of radiation applied could any certain reaction on the part of the respiratory exchange be established *after* radiation; in most cases the findings were exactly the same before and after radiation. Only in a few tests with the blue light was an increase found after radiation, which, however, was so slight (4.6 % and 5.3 %) that one cannot attach any importance to it.

As for the respiratory exchange during the various types of radiation, a very interesting fact was revealed, i. e. that the shorter the wave-lengths used for radiation, the more manifest becomes the tendency to increased metabolism. The respiratory exchange

must be said to be quite unaffected by the yellow light energy. The minimal deviations from the zero observed during radiation with yellow light must decisively be considered as falling within the limits of error. Owing to the somewhat uncertain values for contraction and the special temperature conditions during radiation, — the front temperature not being identical to the back temperature —, determination of the respiratory exchange *during* radiation will always involve greater uncertainty than determination of the respiratory exchange *after* radiation. The fact that no more distinct reactions occurred during the yellow radiation, the records of the manometer being constantly near zero, I consider a confirmation that the experimental technique has been unobjectionable and serving its purpose well. And, consequently, when the value for oxygen consumption with other types of radiation was found to lie constantly a good deal above zero, this must signify real increase in metabolism in the cases concerned. Thus, if the increase in oxygen absorption is nought in the yellow light, it may be estimated to be about 10 per cent in the blue light and about 20 per cent in the light emitted through the glass-filter. In radiation with the unfiltered light of the KROMAYER-lamp the increase amounted to about 40 per cent. That is to say, a distinctly increasing reaction the farther we move into the short-waved region of the spectrum. The results of the radiation tests with blue and yellow light of 1925 show the best possible harmony with the experiments of 1918, since, neither at that time could the yellow light be detected to excite any reaction on the part of the respiratory exchange, whereas a reliably established accelerating effect of the blue light was observed *during* radiation, though no after-radiation.

In regard to all the four types of radiation obtâins that it made no perceptible difference in the effect on metabolism, whether the intensity of the light was varied, within the definite range employed; it must be borne in mind, however, that even the weakest intensity employed is really a very strong intensity.

Before commencing the experiments of 1925 communicated in this work, I had carried out a fairly long series of similar experiments, though using a minimal power of light for radiation, the chrysalids being exposed partly to luminous and partly to ultraviolet spectral bands emitted by a powerful spectral apparatus supplied with lenses and prisms made of quartz and a mercury-quartz burner. In these experiments I found no appreciable reaction on the part of the metabolism of the pupæ. For completeness' sake I shall just describe one of these experiments, otherwise I find no occasion to go into further details about them.

Owing to the special construction of the spectral apparatus it was necessary in these tests to remove the spirometer from the water-bath during

radiation so that the respiration-chamber containing the chrysalid could be placed in front of the slit of the apparatus. Therefore, the temperature of the chrysalid could not be kept absolutely constant during radiation.

Test date 22/10. Bath-temperature 19.2° C.

Oxygen consumption prior to radiation observed for 150 minutes to be constant per 15 min. periods at 3.0 mm.

Oxygen consumption 10 min. subsequent to radiation observed for 70 minutes to be constant per 15 min. periods at 3.0 mm.

Exposure 45 min. by spectral line 313 $\mu\mu$, the chrysalid being placed at 1 cm from the slit. The rays particularly strike the posterior portion of the body, across its whole width. During radiation the pupal temperature rose from 19.2° to 20.2°, the average being 19.5°. (The rise is due to the room-temperature being slightly higher than the bath-temperature, and can scarcely to any appreciable extent be attributed to the action of the light.) The increase in the oxygen intake recorded during radiation was 9.5 mm, while the normal finding for 45 mm at 19.2° is 9.0 mm. The difference — 0.5 mm — agrees fairly well with the increase one might expect to find owing to the rise in temperature during exposure; any specific reaction due to the light was thus not observed.

Some Deliberations and Experiments Concerned with the Causation of the Observed Influence of Light upon Oxygen Consumption

1) *The Temperature Conditions of the Pupa during Radiation*

It is well-known that the increase in the metabolism of cold-blooded animals is to a certain extent proportional to the changes of temperature. The experiments which bear out this theory were however presumably all made under conditions in which the temperature of the animal experimented upon and the surrounding temperature were more or less alike, or, in other words, the thermal emission from the animal has been quite minimal, as, after standard conditions being re-established, no thermal energy has been emitted to the animal from the outside. Quite differently, in the experiments of this work, in which a considerable quantity of calories is continually irradiated to the chrysalid, so that, when the absolute temperature of the animal is none the less kept constant or approximately so throughout the tests, this can only be effected by a simultaneous increase of the thermal emission from the animal, which is effected by reducing the temperature of the water-bath and, consequently, that of the ambient air. Anticipatively, it was perhaps not unthinkable that such a lively transport of calories within the organism might in itself give rise to augmented metabolism, the increase thus being not a specific light phenomenon, but only a manifestation of the lively interchange of calories in the organism, owing to the irradiation and re-emission of calorific energy. That the re-

sults obtained in the present work are not due to such a calorific action becomes however evident through a closer study of the experimental results. For, the increase in the respiratory exchange during radiation is in these tests by no means proportional to the amount of calories irradiated, as has been pointed out on several occasions. This holds good not only when we consider one definite type of radiation, but it becomes still more striking, if we compare the different types of light in this respect, more particularly the yellow light with the unfiltered light. The former type of light did not excite any metabolic reaction, while the latter elicited considerable increase, in spite of the fact that in the yellow light the quantity of the calories may amount to 0.41, with no effect, a calorific energy many times greater than that of the unfiltered light which, for instance, is 0.02 calories, the latter nevertheless having a marked accelerating effect on metabolism. Thus, there are no data to bear out the assumption that the irradiation of calories should be responsible for the effect upon the respiratory exchange.

2) *Does Radiation of the Air give Rise to the Generation of Gases which May Influence Oxygen Consumption?*

Data are scarcely at hand which would anticipatively make such a supposition plausible. Still, my undertaking these special investigations are due to the so-called contraction-phenomenon observed during the experiments, the presence of which I did not anticipate. As previously mentioned it must be taken for granted that certain new gases will be generated if a sufficient amount of light energy is irradiated not only in radiation with short wave-lengths, although mainly with such, but also in radiation with yellow light of long wave-lengths. That I was not able to demonstrate any action on the oxygen consumption derived from these gases, has already been mentioned, in the following I shall try to prove this contention.

The experiments made for this purpose were performed exactly in the same manner as the other radiation-tests, except that the front of the chrysalid was covered by a small tin-foil screen permitting the air around the insect to be radiated, but preventing the insect itself from being directly exposed to the rays. The temperature of the chrysalid which was of course influenced by the temperature of the tin-foil screen in front, was regulated to a constant level by means of the water-bath temperature, as was previously described.

In all the tests the quartz-pane of the respiration chamber had an uncovered area of 110 mm^2.

Table 5

Oxygen Consumption in Tests where the Air Surrounding the Pupa, though not the Pupa itself, is Exposed to Radiation

No.	Date	Type of radiation	Calories	Bath temp.	Temperature of pupa during radiation			Oxygen intake per 15 min.		Manometric record during radiation for 45 minutes	Normal respiratory exchange for 45 min.	Difference	The contraction value previously found
					Front		Back	Prior to radiation	Subsequent to radiation				
					Maximum reaction	Average temp.							
1	5/12	Unfiltered light	0.62	19.9	20.0—19.8	19.8	20.0	2.3	2.3	7.8	6.9	0.9 mm	0.7 mm
2	6/12	Do.	0.83	18.6	18.6—18.6	18.6	18.5	2.7	2.7	9.0	8.1	0.9 »	0.7 »(0.5)
3	9/12	Blue light	0.35	20.0	20.0—19.8	19.9	19.9	4.5	4.5	13.8	13.5	0.3 »	0.5 »
4	7/12	Yellow light	0.41	21.2	21.4—20.9	21.2	21.2	4.2	4.2	12.8	12.6	0.2 »	0.2 »

In none of these tests was there any detectable reaction of the respiratory exchange either during or subsequent to radiation. The difference found between the value for the normal oxygen absorption without radiation, and the manometric record during radiation of the air surrounding the chrysalid agrees as exactly as desirable with the known contraction of the air volume under the given conditions of radiation. Thus, the gases generated during radiation had no effect on metabolism, as was anticipated.

3) *Experiments on the Influence of Light on the Oxygen Consumption in Surviving Tissue from the Chrysalids*

Originally, the tests to be described here were not initiated for the purpose of studying the effect of light upon metabolism in surviving tissue. What I desired to find out was whether the light energy when striking the surface of the chrysalid could give rise to a further contraction of the air-volume in the respiration chamber beyond that evoked by the passing of the light-rays through the air in the chamber. Beforehand, this did not seem probable; however, I found it right to make perfectly sure on this point, in order to be able to definitely exclude that the results obtained in this work as to the accelerating influence of light on metabolism should be due

alone to a possible interaction between light, air, and surface of the chrysalid, with ensuing molecular contraction of the air, so that the respiratory exchange of the animal was in reality not involved at all.

Therefore, in some experiments, I exposed a pupal skin from which all the contents had been removed, to radiation. This was done in the following manner: by means of a thin GRAEFE knife, I excised a strip of surface skin, about 1 mm wide, along the middle of the back of the animal; further from the top part of the head I excised a circular area of skin about 1.5 mm in diameter. Through these openings I removed as far as possible the entire contents by means of a pair of fine, slightly curved oculists' pincers. Apart from the small holes on the back the exterior of the chrysalid presents itself perfectly as in the live normal animal, and it may be suspended in the respiration chamber in the usual manner by means of the thermo-needles, except that the »back» needle will enter a little through the slit on the back. Determination of the »back»-temperature has therefore also been out of consideration, it being on the whole of minor importance.

It appeared in the tests that this pupal skin, presumably owing to parts of muscular tissue left on the inside, had an oxygen consumption exactly similar in value to that of the living pupa, such as appears from a comparison between the table below and previous tables.

Before proceeding to account for the metabolic reactions of this pupal skin when exposed to radiation, I shall briefly state its reactions to changes of temperature, as I found them in an isolated test: A pupal skin which, at 16.3° C., had an oxygen absorption of 1.2 mm in four 15 minute periods (observed for 60 minutes in all) (1.2 — 1.2 — 1.1 — 1.2), showed afterwards at 20.4° C. an absorption of 1.8 mm in four 15 minute periods (1.8 — 1.8 — 1.8 — 1.8). Thus, the addition of one thermal degree, at the given temperature, gave an increase of 12.5 %, while, in previous tests, I had found an increase of 16 % under the same conditions in living chrysalids.

The metabolic processes in surviving pupal skin are thus increased by heat, just as in the case with regard to the metabolism of the living pupa. Now, if the pupal skin were likewise found to react to the influence of light by an increased metabolism, according to the same laws as those found to obtain for the living pupa, I had not come any nearer to the solution of the problem whether mere radiation of the pupal skin could give rise to a contraction of the air-volume, which might simulate an increase of oxygen absorption. The following 4 radiation tests with surviving pupal skin were made: the technique was exactly like that of the tests with living pupæ. The area of the quartz-pane of the respiration chamber covered 110 mm^2.

Table 6

Oxygen Consumption by Surviving Pupal Tissue Exposed to Radiation

No.	Date	Type of radiation	Calories irradiated per cm² and per min.	Bath temp.	Temperature of pupal skin during radiation		Oxygen intake per 15 min.		Radiation for 45 minutes			Increase in oxygen consumption	
					Maximum reaction	Average	Prior to radiation	Subsequent to radiation	Manometric record calculated	Contraction	Respiratory exchange	During radiation	After radiation
1	15/12	Unfiltered light	0.62	19.6	19.6—19.5	19.6	1.65	1.75	5.5	0.7	4.8	÷ 3.1 %	6.1 %
2	16/12	do.	0.62	18.7	18.8—18.5	18.7	1.7	1.75	5.4	0.7	4.7	÷ 8.5 %	2.9 %
3	18/12	Blue light	0.35	18.8	19.1—18.6	18.8	2.6	2.5	7.9	0.5	7.4	÷ 5.1 %	÷ 3.8 %
4	19/12	do.	0.35	19.0	19.2—18.8	19.0	2.65	2.7	8.3	0.5	7.8	÷ 1.9 %	1.9 %

The noteworthy fact told by these figures is that, with the radiation applied, which invariably would have brought about a rise in the oxygen consumption by the living pupa, no metabolic reaction[1] was found to occur in the surviving pupal skin. Thus, the results can involve no error owing to a possible air-contraction caused by the light effect upon the pupal skin.

The fact that light has no accelerating action on the oxygen consumption of the surviving tissue, is also of considerable interest in another respect. As observed in the introductory remarks, one cannot expect a direct effect on the cells especially concerned in the metabolic processes by exposing an opaque animal to light energy. If a reaction is nevertheless seen to occur, it must be caused indirectly, for instance through the nervous and vascular systems. The experiments stated above, seem to corroborate this theory very neatly: for, when the nervous and vascular systems are removed, no reaction is excited by the light, the metabolism remaining unaltered.

Of course, one might still wonder whether the increase in the metabolic processes could not, after all, be due to an increase of muscular tone during radiation, a muscular tension which, it is true, is not manifested in observable movements, but which might still

[1] There can scarcely be a question of any decrease in metabolism owing to radiation; the negligible decrease during radiation found in the table is undoubtedly due to the value for contraction, which, in this case, has perhaps been estimated a little too high.

exist. As previously said, it is difficult to imagine that these pupæ should occasionally be subject to an increased metabolic activity from this cause. The perfectly uniform and steady metabolism which is usually found all through pupal life does not indicate that the muscular tension of the insect would now and again be augmented. This reasoning, however, is not absolutely conclusive, for even though the pupa otherwise never increased its muscular tone, it might of course do so under such exceptional conditions as exposure to a strong radiation. In my experimental results there is however a single factor which, in my opinion, may serve to further refute the theory of augmented muscular tone. It is the almost regular incidence of a persisting considerable increase in the oxygen consumption after exposure to ultraviolet light, an increase which was found to be maintained at a constant level for a long period, sometimes watched for several hours after the experiment was discontinued. It is hardly conceivable that an increase of muscular tone could be maintained at so constant a level, eliciting an exactly uniform metabolic reaction during such a long period. Therefore, I feel quite convinced that the metabolic reaction persisting *after* radiation at any rate, can have no connection with a change in muscular tone; and, that the reaction found *during* radiation should, in principle, be of a different nature, would be a rather farfetched supposition. The action of this strong light energy, thus evidently produces radical changes in the organism, changes which, at any rate in this respect and presumably also in other ways, may be correlated with the radical changes wrought on the mineral metabolism by the same light energy.

As for the relation of my experimental results to a possible investigation of the influence of light upon the oxygen consumption by larger animal species, for instance man,[1] it must be borne in mind that radiation of so small an animal as the chrysalid of the mealworm, where one half of the animal is exposed, the light still to some extent penetrating below the surface, must be considered a very vigorous action, in that very considerable parts of the total volume of the body are simultaneously exposed. The larger the animal, the relatively smaller the part of the body that can come

[1] Later on I have seen that KESTNER, PEMØLLER and PLAUT (Kl. Wochenschrift Nr. 44, 1923) have made investigations into the influence of ultraviolet rays upon the oxygen consumption by man and have found that a rising of this takes place during the radiating. As I have said formerly it is difficult to attach any decisive importance to such experiments where the muscle-activity has not been interrupted; however, as no effect was produced by the visible light but only by the ultraviolet, it may be possible that the author has had to do with the same effect which I have described.

directly under the influence of the light. The metabolic reaction will determine, therefore be proportionally less, perhaps even so small as to be difficult to detect, the more so in view of the fact that, normally, the respiratory exchange in higher animals is not approximately maintained at so constant a level as it is in a pupa which takes no food.

SUMMARY

1) Radiation with strong light energy (ranging from about 0.02 to about 1.00 gram. caloric per minute and per square centimeter) of certain light qualities has a considerable accelerating influence on the oxygen consumption by the chrysalids of the meal-worm.

2) The effect is the greater, the shorter the wave-lengths applied, since an increase of oxygen consumption of

about 40 % was found at exposure for 45 minutes to the unfiltered light of a KROMAYER-lamp,
» 20 % » » when a glass-filter was used,
» 10 %, with a glass-filter and a methylene-blue filter, and
0 » » » » potassium-bichromate filter.

Thus, the yellow light has no influence on the respiratory exchange.

3) Within the ranges of intensities applied in the radiation experiments no difference of effect could be detected, no matter whether a stronger or a weaker radiation of the same type of light was employed.

4) *Subsequent* to radiation with the unfiltered light an increase of the oxygen absorption of about 15 per cent. on an average, was established to persist for a lengthened period in nearly all the tests. In the cases where it was examined, this increase was kept at the same level several hours after discontinuance of radiation. In the experiments with filtered light, in which the essential portion of the ultraviolet frequencies are cut off, no after-effect on metabolism could be detected.

5) The pupæ, which had been exposed to the unfiltered light, presented a blackish pigmentation on the day following the experiment, and died in the course of a few days, while the animals which had been exposed to the other types of radiation would continue their development undisturbed.

6) Surviving tissue from a pupa, obtained by removing with a pair of pincers the major part of the soft tissue from a freshly killed pupa proved, presumably owing to the presence of plenty of muscular cells on the inside of the pupal skin, to have an oxygen consumption of the same order as a live pupa. This oxygen absorption in the surviving tissue reacted to changes in temperature in a similar way as in the live animal, while the metabolic processes in the pupal skin did not react to a radiation which, in the living pupa, produced an increase of metabolism.

Therefore, it is assumed that the accelerating action on metabolism produced by light in the living pupa depends on the presence of nervous or vascular tracts, being thus due to radical changes in the organism, which may perhaps be correlated with the well-known effect of light on the mineral metabolism.

ZUSAMMENFASSUNG

1) Bestrahlung mit starken Lichtenergien (ungefähr 0.02 bis ungef. 1.00 g Kal. pro Minute und Quadratzentimeter) von gewissen Lichtarten hat einen erheblich beschleunigenden Einfluss auf den Sauerstoffverbrauch der Puppe des Mehlwurms.

2) Je kürzer die verwendeten Wellenlängen sind, umso grösser ist die Wirkung, indem man eine Steigerung des Sauerstoffverbrauches von ungefähr 40 % fand, wenn die Puppe durch 45 Minuten dem unfiltrierten Licht einer KROMAYER-Lampe ausgesetzt wurde, während man nur ungefähr 20 % fand, wenn ein Glasfilter benutzt wurde,

ungef. 10 % bei Verwendung von einem Glasfilter und einem Methylenblaufilter, und

ungef. 0 % bei Verwendung von einem Glasfilter und einem Kalium-Bichromatfilter.

Das gelbe Licht hat also keinen Einfluss auf den respiratorischen Umsatz.

3) Im Bereich der bei den Bestrahlungsversuchen verwendeten Intensitäten konnte kein Unterschied in der Wirkung entdeckt werden, ob eine stärkere oder schwächere Bestrahlung mit Licht vom selben Typus vorgenommen wurde.

4) Auf die Bestrahlung mit unfiltriertem Licht *folgend*, trat, wie konstatiert werden konnte, bei nahezu allen Versuchen eine durchschnittlich ungefähr 15 %ige, durch längere Perioden anhaltende Steigerung der Sauerstoffabsorption auf. In den Fällen, die darauf untersucht wurden, hielt sich diese Steigerung mehrere Stunden nach dem Ende der Bestrahlung auf demselben Niveau. In den Experimenten mit filtriertem Licht, bei welchen die ultravioletten Strahlen im wesentlichen ausgeschaltet waren, konnte keine Nachwirkung auf den Stoffwechsel entdeckt werden.

5) Die Puppen, die dem unfiltrierten Licht ausgesetzt gewesen waren, zeigten am Tage nach dem Experiment eine schwärzliche Pigmentation und starben im Verlaufe von einigen wenigen Tagen, während die Tiere, welche Bestrahlungen der anderen Typen exponiert worden waren, sich ungestört entwickelten.

6) Überlebendes Gewebe von einer Puppe, das gewonnen war, indem man mittels Pinzetten den grösseren Teil des weichen Gewebes einer frisch getöteten Puppe entnahm, zeigte — vermutlich infolge des Vorhandenseins einer Menge von Muskelzellen an der Innenseite der Puppenhaut — einen Sauerstoffverbrauch vom selben Grad wie eine lebendige Puppe. Diese Oxygenabsorption im überlebenden Gewebe reagierte auf Temperaturveränderungen in ähnlicher Weise wie beim lebenden Tier, während die Stoffwechselprozesse in der Puppenhaut auf eine Bestrahlung, die bei der lebenden Puppe eine Umsatzsteigerung hervorrief, nicht reagierte.

Verf. nimmt deshalb an, dass die in der lebenden Puppe durch Licht hervorgerufene, beschleunigende Wirkung auf den Stoffwechsel von dem Vorhandensein nervöser oder vaskulärer Teile abhängt, also auf radikalen Veränderungen im Organismus beruht, die vielleicht mit dem wohlbekannten Effekt des Lichtes auf den Mineralstoffwechsel in Beziehung stehen.

RÉSUMÉ

1) Des irradiations de forte intensité lumineuse (de 0.02 à env. 1.00 gr. calorique par minute et par centimètre carré) pratiquées avec certaines catégories de lumières, déterminent une accélération marquée de l'absorption d'oxygène chez les chrysalides du ver de farine.

2) Cette influence est d'autant plus accentuée que la lumière appliquée a une longueur d'onde plus réduite; une irradiation de 45 minutes avec la lampe de KROMAYER non filtrée augmente l'absorption d'oxygène d'environ 40 %. Cette augmentation est d'environ:

20 % avec filtre de verre,
10 % » » » » et filtre au bleu de méthyle,
0 % » » » » » » au bichromate de potasse.

La lumière jaune n'a donc aucune action sur les échanges respiratoires.

3) Au cours des expériences d'irradiation, aucune différence d'effets n'a été notée, relative aux diverses intensités utilisées, pas plus qu'on n'a pu attribuer un rôle quelconque à la qualité, molle ou dure, des irradiations provenant d'une même source lumineuse.

4) *Consécutivement* à l'irradiation de lumière non filtrée, il a persisté chez presque tous les témoins et pendant une période assez longue, une augmentation de l'absorption d'oxygène s'élevant en moyenne à 15 %. Dans les cas examinés, cette augmentation se maintenait au même niveau plusieurs heures après la cessation des irradiations. Dans les expériences faites avec lumière filtrée, et dans lesquelles la majeure partie des rayons ultra-violets se trouvait par suite éliminée, on n'a observé sur le métabolisme aucun effet consécutif.

5) Les chrysalides exposées à la lumière non filtrée présentent, le jour qui suit l'irradiation, une pigmentation noirâtre et meurent au bout de quelques jours, tandis que les individus soumis aux autres types de radiations continuent leur développement normal.

6) Les tissus survivants prélevés sur une chrysalide récemment tuée en arrachant à l'aide d'une pince la majeure part des parties molles, présente, en raison sans doute de la présence, sur la partie interne de l'enveloppe, d'une quantité de cellules musculaires, une absorption d'oxygène égale à celle de la chrysalide vivante. Cette absorption d'oxygène des tissus survivants réagit aux changements de température de la même façon que l'animal vivant, tandis que le processus métabolique de l'enveloppe chrysalidique reste indifférent aux radiations qui, chez la chrysalide vivante, provoquent une augmentation du métabolisme.

Il est donc à présumer que l'action accélératrice déterminée par la lumière sur le métabolisme chez la chrysalide vivante est due à la présence de tractus nerveux ou vasculaires issus de modifications radicales de l'organisme, phénomènes que l'on pourrait peut-être comparer aux effets bien connus de la lumière sur le métabolisme minéral.

A CIRCULATING PHYSICAL DEPARTMENT FOR STANDARDISING THE ROENTGEN RADIATION USED IN THERAPY

by

Rolf M. Sievert

There is no doubt that the ideal solution of the dosage problem in roentgen therapy is to be able to state sufficiently accurately what quality and quantity of radiation have worked in every separate part of the object under treatment. Is it possible to do this with the resources that physical science at present has at its disposal? This question can only be answered in the negative. The efforts which have been made to solve the dosage problem, at least approximately, seemed at first to be crowned with success, it must be admitted, but it is obvious from the more critical investigations of late years that much remains to be done before a "physical dosage" of this nature comes up to even fairly modest requirements. The physical dosage question has come to an impasse. It is of course interesting to measure, with the help of a fairly cleverly constructed measurement apparatus, the distribution of intensity in a more or less accurate copy of the human body, and subsequently endeavour to find the relationship between the therapeutic effects and the physical dosage observed; looking, however, more closely into the matter, it must be acknowledged that such a process cannot as yet be carried out to advantage. It does more harm than good, as it easily leads us to suppose that the work is exact physically, and such is really not the case.

But what is to be done in order to attain greater accuracy with regard to dosage, and gradually to gain more profound knowledge as to the therapeutic effects of the roentgen rays? The answer is to be found largely in statistics. The conditions that enable us to apply such methods successfully in roentgen therapy are of two kinds. Firstly, so many physical facts must be known at every treatment so that the dosage given can be definitely determined and

fixed with sufficient accuracy so that it can be reproduced; secondly, we must have as much material as possible at our disposal. The latter condition is closely allied to the former, inasmuch as a comparison between results is only possible if all roentgen therapeutists work with dosage based on the same methods of determination. These simple, and to a certain extent, self-evident principles form the basis of the establishment of a "Circulating Physical Measurement Department" which was planned about two years ago and has now been at work for six months. It is in consequence of this that I am here going to give a short account of the working methods that are being made use of.

First of all it is necessary to state the facts which should be investigated in every roentgen department. These may be divided into

1) those factors which do not bear upon the determination of the radiation, but only upon the control of the apparatus and refer to its accuracy and economy. In this connection will be noticed

The consumption of current.

The variations of primary voltage and their influence on the total radiation.

The degree of fine regulation for voltage and milliampère.

The reliability of the milliampère-meter.

» » » » kilovolt-meter.

The filter.

The presence and intensity of high frequency.

The durability and suitability of roentgen tubes.

2) those facts which define radiation, and which should as far as possible always be the same. For every filter and voltage used these are:

Qualitative

The peak voltage.

The voltage curve or roentgen spectrum and deep dosage.

Quantitative

The milliampère.

The ionization power of the radiation.

We have, moreover, the facts which define every separate treatment, and which should of course be recorded in every separate case:

The distance between the focus and the skin.

The primary dosage of the skin.

The duration of the treatment.

The size of the field and the position of the cluster of rays on the human body.

The consumption of current is measured by an ampèremeter which is connected to the line and furnished with a switch so that the measure area of the instrument can be changed to suit the limits required. The importance of the consumption of current for economy is, in most cases, comparatively small. On the other hand, however, it is of interest to know the consumption for the different types of apparatuses when a new one is being installed. Certain faults in the apparatus cause an increased consumption of current. At Radiumhemmet we have had the opportunity of observing cases in which an unusual consumption of current has directly shown the nature of the fault.

The variations of primary voltage often have a rather important effect on the work of the apparatus. They are examined with the help of a self-registering volt-meter connected to the line. Some apparatuses are much more sensitive than others to such variations, and this to such a degree, that with some an increase of voltage in the line causes an increased radiation intensity; with others, on the other hand, it brings about a decrease, provided that in both cases the apparatus is so handled that the kilovolt-meter and milliampère-meter give constant values. In order to be able to examine these variations I have constructed a self-registering arrangement combined with an apparatus for intensity-measurements.[1] Fig. 1 shows a curve taken with this apparatus.

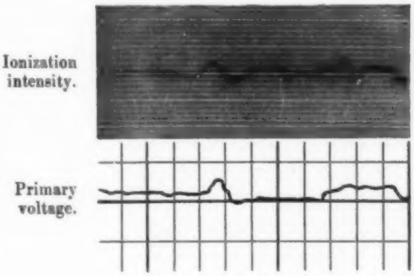


Fig. 1.

The arrangement for *the regulation of the milliampère and the voltage in the high tension circuit* is, as we know, very different with different apparatuses. There is not even any fine regulation arrangement attached to some of the old-fashioned ones, and in such cases we are obliged to work with the regulators in fixed positions, and only to see that the milliampère shows the value desired. It is obvious that with such apparatuses the intensity variations of the primary voltage may cause considerable variations in the radiation. With the apparatus for intensity measurements, which I have just mentioned, upon which the radiation intensity can be followed every second, it is easy to determine in a couple of minutes how great the radiation differences are between the different buttons. When

[1] Comp. R. M. Sievert, Acta rad. IV, 1925, p. 129.

visiting some of the hospitals in Sweden, I have noticed repeatedly that the controlling arrangements with even some of the modern instruments are so badly constructed that there is hardly any proper fine regulation at all.

The control of the milliampère-meter by means of a precision instrument connected in a series with the milliampère-meter of the apparatus often gives surprising results. The precision instrument must naturally be well insulated towards the earth. If the instruments disagree it is, as a rule, only necessary to take two kinds of faults into consideration. One is to be found in the milliampère-meter itself, and is generally of little importance when fixing the dosage, it being most often constant. The other is due to the high tension which often causes chargings on the glass of the milliampère-meter, and the indicator is in consequence influenced by attraction powers. Let me give an example. When using two tubes at the same apparatus and measuring the intensity of both, about 30 % greater intensity was obtained from one of them, in spite of both the milliampèremeters having the same deflexion. The cause of the fault was owing to the chargings of the glass. According to JAECKEL,[1] similar faults up to even 100 % have been observed. At Radiumhemmet we generally apply a mixture of water and glycerine to the surface of the glass every week in order to avoid similar occurrences. Glycerine, as we know, is hygroscopic, and provides the glass with a thin, conductive coat of water.

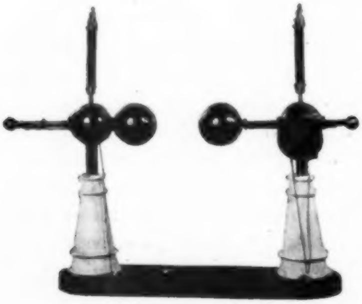


Fig. 2.

The kilovolt-meter accompanying the apparatus is generally known to be anything but accurate. As a rule it shows too high or too low a kilovoltage, and this necessitates a correction of the graduation. This correction most often depends on the loading of the apparatus, and is consequently somewhat troublesome. This is especially noticeable with two tube work. For example, at Radiumhemmet we have an apparatus, which, in order to obtain the same voltage, must be worked at 195 kilovolt when using one tube, while for two tubes it requires 210 kilovolt. In both cases the actual peak voltage is about 170 kv. It is easy to decide by means of a sphere-gap what a fixed deflexion on the kilovolt-meter

[1] G. JAECKEL, Fortschr. a. d. Geb. d. Röntgenstr. Kongressheft 2, 1922, p. 202.

signifies in peak voltage. Fig. 2 shows a suitable spark-gap, which at my suggestion has been fitted up with a little arrangement, somewhat different from the usual kind, as it is possible to set one of the spheres for a certain sparking distance and afterwards to control the spark by moving the other sphere to an 0-position. The latter sphere is furnished with a springy arrangement to make it possible to break off the spark quickly. Even with a comparatively high resistance attached to both sides of the sphere-gap care should be taken not to let the sparks pass across for more than a few seconds. Immediately the spark begins to pass through the air the resistance between the two spheres decreases to such an extent that the loading of the apparatus increases tremendously. It is not advisable to make use of such great resistances so that the risk of damaging the apparatus is entirely eliminated, as the values then obtained are far more likely to be inaccurate.

The control of the filter must also be taken into account. Besides ascertaining the thickness of the filter, a roentgen plate should perhaps be taken in order to detect any weaknesses.

The existence of high frequency is rather often the reason why roentgen tubes must be discarded so soon, just as the tubes in their turn often cause high frequency. Attempts have been made to prove in a simple and practical way the existence of high frequency, and when possible the tubes should be examined in order to discover this.

The control of the roentgen tubes involves among other things the taking of a focus photograph for every tube. We began to examine our tubes at Radiumhemmet in this manner about one year ago, and it seems as if with a little experience it ought sometimes to be possible to judge the quality of a tube from the focus photograph. In some cases, at any rate, it is possible to see that the tubes will not last long. Figs 3, 4 and 5 show how the focus of a tube can change under certain circumstances. We see that the focus spot has been enlarged and extended over the edges of the target. A great many

Fig. 3.

Fig. 4.

Fig. 5.

of the electrons have consequently passed the target, and have caused disturbances which have gradually rendered the tube unfit for use. The first photograph was taken when the tube was new, and even there we can see that the focus is not in the middle of the target. When the latter photograph was taken the filament bent outwards from the centre. Those tubes, which on examination are found to possess such irregularities, are now sent back to the makers. The radiological institutes which employ the Circulating Measurement Department intend to draw up statistics of the tubes they use and hand them over to the said department.

Let us now pass on to the determination of roentgen radiation. Perhaps we had better first of all look at this question from a purely theoretical point of view. What is of interest to us is the radiation which reaches the patient after it has passed eventual filters. For this radiation let us imagine a curve which completely determines the quality and quantity of the radiation. Fig. 6 shows what the approximate appearance of the curve would be. The radiation is thus defined, qualitatively in consequence of the existence of different wave-lengths, and quantitatively on account of a certain intensity corresponding to every wave-length. It would involve too much here to decide whether such a curve can be constructed or not, we must content ourselves with the knowledge that in practice it would prove complicated for various reasons. We must therefore, for the present, confine ourselves to examining facts which have a direct influence on the appearance of the curve.

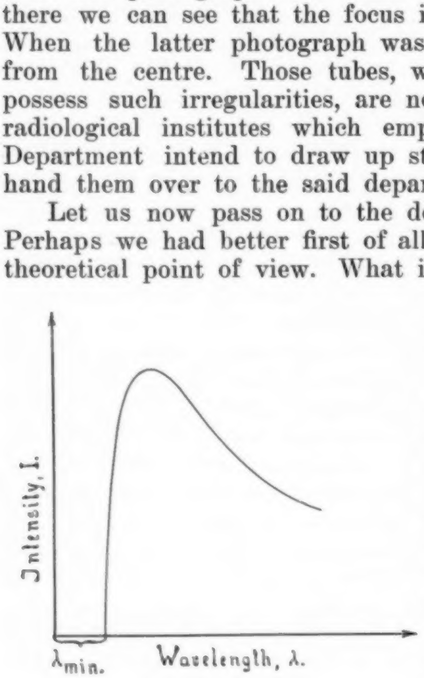


Fig. 6.

If we first look at the *quality of the radiation* we find that this is given to a certain extent by the peak voltage, i. e. the highest tension there is between the poles of the tube at every current impulse. We know that the highest tension determines the smallest wave-length which is to be found in roentgen radiation, the minimum wave-length (λ) being obtained from formula $\lambda = 12.35 : V$, V being the number of kilovolts. Thus, with one and the same apparatus the quality is fixed, inasmuch as the peak voltage and filter are given.

In order to compare different apparatuses, it is necessary to know *the voltage curve at the tube*, or to have a spectograph to judge ap-

proximately the relationship between *the intensity curves of different apparatuses. Deep dosage measurements* may also be carried out as a further control of the average quality of the rays. These measurements are, moreover, of value when forming an idea of the distribution of the radiation in the tissue.

The *quantity*, again, is all but in proportion to the *milliampère*, provided that the other factors are constant. The best means of ascertaining this quantity is to examine *the ionization power of the radiation.*

The statements we thus obtain indirectly determine with sufficient accuracy the curve to which reference has just been made. In other words, when we are once able to construct such curves we have sufficient data to arrange curves at least approximately for radiation previously used.

When investigating radiation we make use of instruments, some of which have been constructed at Radiumhemmet. For the quality measurements we have the sphere-gap, a Seemann-spectrograph and a deep dosage instrument which is described in another part of this journal.[1]

The above mentioned portable galvanometric apparatus for the measurement of intensity has proved both strong and reliable. It has been calibrated at the Physikalsch-Technische Reichsanstalt in Berlin, so that the intensity can be obtained in R. per min. Every Roentgen ward which employs the Circulating Measurement Department is going to be supplied with an instrument, somewhat less complicated, but constructed on the same principle. Figs. 7 and 8 show the principle and the appearance of this apparatus. The instrument is only intended to control the radiation week by week and to see that it remains constant, which after a standardization is the only essential.

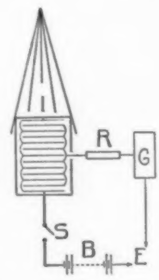


Fig. 7.

I ionization chamber.
R resistance, 1/2—1 mill. ohm.
E earth.
B battery.
S switch.

We have now spoken of the control of apparatuses, tubes and radiation, and we now come to the facts, which must be considered when treating a patient. Here the medical man with his practical experience is far better able than the physicist to judge the situation. I have, however, one suggestion to make with regard to the principal question — the standardization. It is my opinion that a standardization of radiation quality, for example, in R units is only a half measure, for there are so many other variable quantities besides radiation intensity which determine the treatment. We can

[1] R. M. Sievert, Acta rad. vol. V, 1926, p. 468.

distinguish four variables which are of great importance when dosing, and which, with certain apparatuses, may be chosen to some extent arbitrarily. These are *peak voltage*, *milliampère*, *filter and distance*. The primary radiation intensity on the surface of the body radiated is determined by these facts. In order to facilitate statistical work it would be best to fix some of these variables to so few values as possible. I should like to suggest that at present these values be determined, when possible, according to this table.

Peak voltage	Transformer	80—130 kv.	160—200 kv.
	Inductor	130—170 kv.	190—220 kv.
Filter		1 mm Al. 2 mm Al. 4 mm Al.	4 mm Al. $^1/_2$ mm Cu + 1 mm Al. 3 mm Cu?
Distance		25, 30, 40, 50 cm.	30, 40, 50, 60 cm.

Fig. 8 a.
Galvanometer on wall bracket.

Fig. 8 b.
Ionization chamber.

I am now, of course, only referring to the Coolidge tube which has now almost completely superseded gas tubes. It must also be remembered that it is not generally advisable to increase the distance beyond 60—70 cm.

Besides the facts already mentioned, there are still others when defining a treatment which should be observed at every radiation. These are: *the primary dosage on the skin, the time of radiation, and lastly the size of the field and the position of the cluster of rays in the body.*

For the present it will be suitable to give *the primary dosage* in average HED fixed in R-units. According to a statistical investigation which has just been made,[1] primary dosages of the following sizes have been suggested.

Filter	R-units
1—2 mm Al	400
4 » »	600
$^1/_2$ mm Cu + 1 mm Al	700

The time of radiation must be noted only on account of dose 1 in time 2 not giving the same therapeutical results as dose 2 in time 1.

[1] R. M. Sievert, Acta rad. VII, 1926, p. 465.

The size of the field and especially the approximate distribution of the radiation in the body involve the greatest difficulties. The best plan would be to have the outlines of the human body printed on cards, which should be attached to the treatment journal, and which should contain the position of the field as well as that of the distribution of radiation.

Before closing, I should like briefly to touch upon the advantages which might be derived from standardization with the help of a central institution. They may be summarized as follows.

Small roentgen departments unable to keep a physical laboratory with apparatuses and a staff would be able to have their roentgen wards controlled by a physicist.

With standardization it would be possible to make comparisons between the results obtained at different hospitals. In this way there would be nothing to prevent a treatment begun at one place in the country from being continued elsewhere, without involving any risk for the patient.

When a new roentgen ward is opened or a new apparatus taken into use, treatments may begin immediately instead of months having first to elapse to experiment with the dosage question.

If the R unit be taken as the international standard it would be possible to compare treatment in Sweden with that abroad.

A greater constancy would be obtained, and consequently a greater certainty with regard to dosage.

A good deal of experience would soon accumulate through people annually visiting the different roentgen departments all over the country, and this would be of assistance when fitting up new roentgen wards and purchasing new apparatuses and tubes.

From these statistics it would be possible to see the achievements of a roentgen tube as well as the length of its life; consequently advice could be given with regard to the most suitable makes and construction for every separate occasion.

The Circulating Department consists of a physicist with an assistant mechanic. Every hospital is visited twice a year, when all the control investigations take place. The results of the investigations made with the above mentioned galvanometer apparatus are sent in every month from the different hospitals. The Circulating Measurement Department is attached to Radiumhemmets Physical Laboratory and is allowed to make use of any instrument the Laboratory possesses. The Circulating Measurement Department is also able to examine the protection arrangements, the voltage used in diagnostic work, radium measurements etc.

SUMMARY

The author describes a Circulating Physical Measurement Department to visit the roentgen wards throughout the country in order to investigate the roentgen apparatus and tubes and to standardize the dosage. A department of this description is combined with the Physical Laboratory of Radiumhemmet, Stockholm, and has been at work for six months and seems to fulfil long existing requirements. The investigations made concern:

1) those factors which do not bear upon the determination of the radiation, but only upon the control of the apparatus and refer to its accuracy and economy. In this connection will be noticed

a) The consumption of current.

b) The variations of primary voltage and their influence on the total radiation.

c) The degree of fine regulation for voltage and milliampère.

d) The reliability of the milliampère-meter.

e) » » » » kilovolt-meter.

f) The filter.

g) The presence of intensity of high frequency.

h) The durability and suitability of roentgen tubes.

2) those facts which define radiation, and which should as far as possible always be the same. For every filter and voltage used these are:

Qualitative:

a) The peak voltage.

b) The voltage curve or roentgen spectrum and deep dosage.

Quantitative:

a) The milliampère.

b) The ionization power of the radiation.

The author proposes that the standardization shall be extended, not only to the dosage but also to several other factors with a view to facilitate statistics.

ZUSAMMENFASSUNG

Der Verfasser beschreibt die Tätigkeit einer »ambulanten, physikalischen Abteilung», die zur Aufgabe hat, periodisch die Röntgeninstitute im Lande zu besuchen und daselbst teils Untersuchungen des Instrumentariums und der Röntgenröhren vorzunehmen, teils die Standardisierung der Dosierung durchzuführen. Eine solche, mit dem physikalischen Laboratorium des Radiumhemmet zu Stockholm verbundene Abteilung ist bereits seit $^1/_2$ Jahre in Tätigkeit und scheint ein längst vorhandenes Bedürfnis zu erfüllen.

Die zur Ausführung kommenden Untersuchungen umfassen

1) solche, die nicht die Bestimmung der Strahlungen, sondern nur die Kontrolle des Instrumentariums und der Röhren in Bezug auf Zuverlässigkeit und Betriebskosten bezwecken. Hierunter gehören:

Stromverbrauch,

Netzspannungsvariationen und deren Einwirkung auf die Gesamtstrahlung,

Grad der Feinregulierung der Spannung und der Milliampère,

Zuverlässigkeit des Milliampèremeters,

Zuverlässigkeit des Kilovoltmeters,

Filtrum,
Vorkommen von Hochfrequenz,
Lebensdauer der Röntgenröhren und deren Zweckmässigkeit im übrigen.

2) solche, die die Strahlung definieren und bei allen Bestrahlungen nach Möglichkeit gleich sein sollen. Diese sind für jedes zur Anwendung gelangende Filtrum und Spannung:

qualitative:
  Scheitelspannung,
  Spannungskurve oder Röntgenspektrum sowie Tiefendosenmessungen,
quantitative:
  Milliampère,
  Ionisierungsvermögen der Strahlung in Luft.

Der Verfasser schlägt zwecks Erleichterung der Statistik vor, auch andere Faktoren als nur den eigentlichen Dosenbegriff zu standardisieren.

RÉSUMÉ

L'auteur décrit l'activité d'une «section ambulante de physique», destinée à visiter les instituts radiologiques d'un pays pour y inspecter, d'une part, le matériel instrumentaire et les tubes terapeutiques, et, de l'autre, normaliser le dosage. Une telle section, adjointe au laboratoire de physique de l'Institut du Radium à Stockholm, a été en service depuis six mois et semble faire face à un besoin réel existant depuis longtemps.

Les recherches entreprises portent sur les points suivants:

1) ceux qui ne concernent point la détermination du rayonnement, mais seulement le contrôle des instruments et des lampes, quant à leur exactitude et à leur économie, entre autres:

la consommation du courant,
les variations de tension des réseaux et leur influence sur le rayonnement total,
le degré du réglage minutieux de la tension et des milliampères,
l'exactitude du milliampèremètre,
l'exactitude du voltmètre,
le filtre,
l'existence de hautes-fréquences,
la durée des tubes terapeutiques et leur utilité en général;

2) ceux qui définissent le rayonnement et doivent être autant que possible les mêmes pour toutes les irradiations. Ceux-ci sont, pour chaque filtre et pour chaque tension:

d'une part qualitatives:
  tension maximum,
  courbe des tensions et spectre radiographique, ainsi que mesure des doses profondes,
de l'autre quantitatives:
  milliampères,
  aptitude du rayonnement à ioniser l'air.

L'auteur propose qu'une normalisation soit également entreprise pour les autres facteurs que la simple notion des doses, dans le but de faciliter les travaux de statistique.

AUS DEM PHYSIKALISCHEN LABORATORIUM DES RADIUMHEMMET IN STOCKHOLM.
VORSTAND: R. M. SIEVERT

EINE EINFACHE, ZUVERLÄSSIGE VORRICHTUNG ZUM MESSEN VON TIEFENDOSEN

von

Rolf M. Sievert

Bei Tiefendosen-Messungen ist es für gewisse Zwecke (vergl. Acta Radiologica vol. V, 1926, S. 457) von Bedeutung, dass man hierzu ein zuverlässiges, von Erschütterungen beim Transport unabhängiges Messinstrument zur Hand hat. In aller Kürze will ich daher eine einfache Vorrichtung beschreiben, die sich in verschiedenen Beziehungen von den allgemein gebräuchlichen unterscheiden dürfte.

Die Konstruktions-Prinzipien waren hierbei folgende:

Die Methode muss die Ionisierungsmethode sein.

Das Instrument muss so konstant wie möglich sein, auch wenn es beim Transport stark erschüttert wird.

Etwaige Fehler am Instrument müssen leicht zu entdecken sein.

Das Messgebiet muss ohne Schwierigkeiten auf alle in der Therapie vorkommenden Intensitäten ausgedehnt werden können.

Tiefendosis und Flächendosis müssen gleichzeitig gemessen werden können.

Um diesen Anforderungen zu genügen, hat sich vollständige Trennung von Ionisierungskammer und Elektrometer alz zweckmässig erwiesen.

Die Vorrichtung besteht aus zwei, mit Kondensator versehenen Ionisierungskammern, sowie einem Einfaden-Elektrometer nach Wulf. Die Centralelektroden der Ionisierungskammern sind mit variablen Radiokondensatoren von ca. 200 cm. Kapazität verbunden. Letztere sind mit Bernsteinisolierung und 4 mm.-Bleischutz versehen. Die Kammern sind aus Backelit und inwendig mit Tusche bestrichen; sie werden mit Hilfe von gewöhnlichen Anodenbatterien bis auf ca. 160 volt geladen.

Die Kondensatoren werden ein für alle Mal so eingestellt, dass man bei gleichzeitiger und gleich langer Bestrahlung an den Kondensatoren die gleiche Spannung erhält. Die Spannung wird ge-

messen, indem man den Kondensator nebst Kammer direkt auf den Elektrometer stellt (s. Fig. 1).

Die Messung der Tiefendosen erfolgt auf folgende Weise:

Die Kammern werden in ein Wachsphantom gestellt (s. Fig. 2) und während einer, zur Strahlungsintensität im geeigneten Verhältnis stehenden Zeit (5—100 sec.) bestrahlt, indem man bei den einzelnen Kondensatoren eine Kurzschlussanordnung ausschaltet und die Exponierung durch Ausschalten des zur Röntgenröhre führenden Stromes unterbricht. Hierauf werden die Kammern wieder herausgehoben, und eine nach der andern mit dem Elektrometer untersucht. Bei dem zur Verwendung gelangten Elektrometertyp waren die Ausschläge, praktisch genommen, proportional den Spannungen, so dass durch

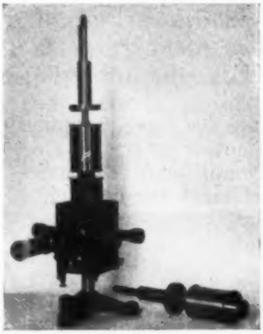


Fig. 1.

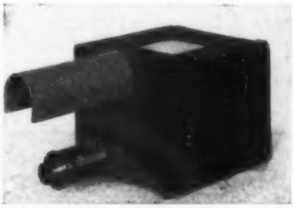


Fig. 2.

eine einfache Division die prozentuale Tiefendosis errechnet werden kann. Sollte irgend ein Isolierungsfehler auftreten, gibt sich dieser sofort durch sichtbar schnelle Entladung des Elektrometers zu erkennen. Die verschiedenen Messgebiete erhält man ohne Schwierigkeiten, indem man entweder die Bestrahlungszeit variiert, oder durch Veränderung des Abstandes zwischen den Elektroden die Empfindlichkeit des Elektrometers erhöht oder vermindert. Die Kammern nebst den Kondensatoren nehmen nur wenig Platz in Anspruch, weshalb man gut z. B. mit 2 Paar solchen arbeiten und sich so in hohem Masse von zufälligen Isolierungs- oder andern Fehlern unabhängig machen kann.

Als Ausgangspunkt für die Tiefendosen-Berechnungen werden in Schweden nunmehr 50 cm. Abstand und 10 . 10 cm. Feld gewählt, was als ungefähr mitten in den gebräuchlichen Gebieten liegend für zweckmässig erachtet werden kann.

ZUSAMMENFASSUNG

Der Verfasser beschreibt ein Instrument für Tiefendosen-Messungen. Dasselbe besteht aus zwei mit Kondensator versehenen Ionisierungskammern nebst einem Elektrometer nach WULF. Die Ionisierungskammern sind vom Elektrometer vollständig getrennt und werden unmittelbar nach der Bestrahlung auf diesen gestellt.

SUMMARY

The author describes an instrument for Deep Dosage Measurement consisting of two ionization chambers combined with capacities and an electrometer according to WULF. The ionization chambers are detached from the electrometer and are placed on this instrument after being exposed to the roentgenradiation.

RÉSUMÉ

L'auteur décrit un instrument de mesure des doses profondes constitué par deux chambres d'ionisation munies de condensateurs et d'un électromètre selon WULF. Les chambres d'ionisation sont complètement séparées de l'électromètre et se placent, après irradiation, directement sur celui-ci.

FROM PROFESSOR HAGLUND'S PRIVATE CLINIC FOR ORTHOPOEDIC SURGERY
AND GYMNASTIC TREATMENT

ON PHOTOGRAPHIC MARKING OF ROENTGEN NEGATIVES

by

Patrik Haglund

Since I began to utilize a Roentgen apparatus in my private clinic in 1902, every plate and subsequently film, has been marked photographically; the advantage of this procedure, employed by many already in the early infancy of roentgenology, is obvious. To give each plate, respectively film, an identification number, to mark right and left side, respectively extremity — with the use of duplitized

Fig. 1.

films almost necessary! — is of very great advantage, particularly so in an eventual search in a roentgenological archive. The forensic importance of photographic marking of negatives, as well as copies and reproductions, should not be underestimated. Finally it is also of great advantage to mark the negative with the name of the institution or the radiologist; such initial marking tells us at once where further, perhaps valuable, information about the case should be sought.

Fig. 2.

The value of photographic marking of negatives, therefore, needs no further discussion. The practical side of the matter, on the other hand, would seem to merit a few lines. The method related by Dr. ARNELL in the fascicle V: 3 of this journal, namely the fixation of metallic letters etc. by means of adhesive plaster, which I utilized for a short time in the beginning of my activity, was soon found to be less practical, than the method I have now been using for more than 20 years.

By putting the desired metallic pieces in some wax they are much easier handled, particularly where numbers composed of several figures are to be fixed, than by fixing them to the casette with adhesive plaster. After some practice the numbering soon becomes automatic, the figures on the wax plate being immediately changed after each exposure; there is only *one* easily manageable object to be fixed. Everything appertaining to the marking is conveniently placed close to the Roentgen table on a small tray. With the wax at a suitable meltingpoint — neither too low, rendering it unpleasantly sticky, nor too high, when the figures donot adhere sufficiently easily — one is able to fix the small plate by its waxy corners to the casette, even when this is placed on the slant or vertically.

Fig. 1 shows my device for marking plates. Fig. 2 shows a picture after having been so marked. Figures and other marks in brass are obtained in every shape and size at firms dealing with gold braids for uniforms, buttons, etc.

The fact of having had all negatives — up to date about 20000 — systematically marked in the above manner ever since the beginning of my activity, has saved much time and trouble in all my research and literary work, as well as also, of course, in routine practice.

SUMMARY

On account of a paper by SIGFRID ARNELL in Acta Radiologica V: 3 the author lays particular stress on the value of marking photographic negatives, and in his opinion plates and films should then also be signed. The author describes the technique he has employed for marking about 20000 Roentgen negatives since the opening of the clinic in 1902. The author further emphasizes how much time and trouble is saved in scientific and practical work by such methodical, photographic marking of negatives; such a method, although in a different way, is also used in the ordinary photography at the clinic.

ZUSAMMENFASSUNG

Anlässlich eines Artikels von SIGFRID ARNELL in Acta Radiologica V: 3. betont Verf. nachdrücklich den Wert photographischer Negativbezeichnung, wobei, wie Verf. empfiehlt, Platten, resp. Filme auch zu signieren wären. Verf. gibt die Technik an, mit welcher er seit Eröffnung der Klinik im Jahre 1902 ca. 20000 Röntgennegative bezeichnet hat, und hebt hervor, wieviel Zeit und Mühe bei wissenschaftlicher und praktischer Arbeit durch eine solche methodische photographische Negativbezeichnung erspart wird, die übrigens, mit einer anderen Technik, auch bei den Kameraphotographien der Klinik vorgenommen wird.

RÉSUMÉ

A l'occasion d'un article de SIGFRID ARNELL, dans les Acta Radiologica V: 3, l'auteur insiste sur la valeur que présente le marquage photographique des négatifs; à son avis chaque film ou cliché devrait également être signé. L'auteur indique la technique qu'il a suivie depuis l'ouverture de la clinique en 1902, pour le marquage d'environ 20000 négatifs radiographiques. Il fait valoir l'économie de peine et de temps que l'on réalise dans des travaux de science pratique grâce à un marquage de ce genre, méthodiquement appliqué et que l'on utilise d'ailleurs avec une technique légèrement différente pour les chichés photographiques ordinaires.

LE SEPTIÈME CONGRÈS ITALIEN DE RADIOLOGIE

Le septième Congrès italien de Radiologie aura lieu à Naples à l'Université R. des Etudes (Corso Umberto I°) les jours 14-15-16 Octobre 1926.

Les thèmes des relations sont:

1. Appareils à haut potentiel et radiations (Prof. ADINOLFI de l'U. R. de Naples).
2. Moyens de contraste dans le diagnostic Röntgen des lésions pulmonaires (Prof. A. ROSSI de l'Université de Parme).
3. Directives radiologiques (Röntgen-radium) pour la thérapie du cancer.
   a. Röntgen: Prof. EPIFANIO de l'Université de Palerme.
   b. Radium: Prof. LUPO de l'Université de Turin.

Une exposition des négatives, diapositives, etc., complétera les démonstrations scientifiques et illustrera les progrès atteints par la radiologie italienne, à laquelle peuvent prendre part gratuitement tous les inscrits au Congrès. En plus il y aura une exposition des principales maisons italiennes et étrangères productrices des appareils et des accessoires pour la Radiologie médicale.

Pour informations, demandes, inscriptions, etc., s'adresser aux Secrétariat (Institut d'Electr. et de Radiologie de l'Université Royale de Naples, S. Andrea delle Dame, 2°).

TO PROFESSOR SLOMANNS PAPER: »ON THE DEMONSTRATION AND ANALYSIS OF CALCANEO-NAVICULAR COALITION» in the foregoing issue of these Acta

Errata

In this paper the following corrections should be made:

P. 304, line 9 from bottom: »see, for comparison, Fig. 2 in the text» — should be: »see, for comparison, his Fig. 9, here reproduced as Fig. 1 in the text».

» » line 8 from bottom: »that they both» — should be: »that his cases both».

» 305, line 9 from top: »(Fig. 2)» — should be: »(Fig. 2 in the text)».

» 306, line 6 from top: »(Fig. 3)» — should be: »(Fig. 1)».

» 308, line 3 and 2 from bottom: »In Fig. 6» to »radiogram». — should be left out.

» 309, line 4 and 3 from bottom in the english summary: »with the lateral border . . . from the photogr. plate» — should be: »with the planta inclined about 45° to the photogr. plate».

» » in the german summary, »Knochenvereinigung» should be changed everywhere to »Koalition».

» » line 2 from bottom: »das Aussehen» — should be: »die Gegenwart».

» 310, line 6 and 7 from top: »bei welcher . . . gehoben war» — should be: »bei welcher die Planta ungefähr 45° zur photographischen geneigt war».

» » line 5 and 4 from bottom: »avec le bord latéral . . . de la plaque photographique» — should be: »avec la plante dans une inclinaison d'environ 45° à la plaque photographique».